3 Regions managing industrial transitions and disruptive innovation

This chapter takes a brief look back across the first three waves of industrial transitions to draw lessons on how regions and cities can ride the current fourth wave. It discusses key elements of the regional innovation system that support a successful transition, as well as different development paths including specialisation and diversification of economic activity. The chapter concludes with a more general discussion of disruptive innovations and how regions and cities can prepare to benefit from their impact.

Introduction

Transitions of the industrial structure in regional and urban economies happen gradually and often imperceptibly, formed by combinations of several innovations. Some of these transitions are “industrial revolutions” that radically alter the way economies function and interact. Many regions and cities contribute to innovations that support “industrial transitions”. No single place drives an industrial transition but all regions and cities have to adapt to them. This does not mean that paths are predetermined but rather requires active and anticipatory changes within regions and cities that ensure that all actors within the region are well placed to seize opportunities that industrial transitions and disruptive innovations can bring.

A combination of innovations can act as a catalyst for industrial transitions where methods of production and consumption change radically. Some regions may find new opportunities for growth but others may find it hard to change their economic model, especially when their industrial structure is too heavily concentrated in economic activities that become obsolete. Regions struggling to manage industrial transitions may require support to diversify their economies and find new paths of growth. Instead of supporting the transition process, policies often aim to retain existing structures, e.g. by subsidising traditional sectors. Replacing policies that aim to retain activity with narrow innovation policies is equally misplaced. Transitioning a regional or urban economy requires a concerted effort of both supply- and demand-side instruments that support the transition of the current workforce and looks forward towards preparing the next generation of workers.

Some authors argue that during the third industrial revolution, European policymakers favoured protecting the stock of existing jobs instead of encouraging innovation and industrial transition. When compared with Europe, the United States took the lead in the third industrial revolution, with the most successful players being US firms (Bloom, Sadun and Reenen, 2012[1]). Decompositions of productivity growth in the United States show that a large fraction of this advantage occurred in sectors that produce information technologies (IT) or use them intensively, while in Europe the disadvantage comes mostly from the lack of IT usage in non-IT sectors (van Ark, O’Mahony and Timmer, 2008[2]). The growing gap arose despite comparably high levels of human capital, talent and research infrastructures in Europe and the United Starts. Part of the explanation can be that Europe focused more on incumbency, helping regions avoiding downward spirals from deindustrialisation (which happened massively in the United States rustbelt). However, by prioritising incumbency, radical innovators can be penalised. As argued in Phelps (2003[3]) and Gordon (2004[4]) European institutions were more prone to protect incumbency and inhibit new entry partly explaining why Europe lagged behind the United States during the third industrial transition.

Industrial revolutions often lead to a displacement of workers or the reduction of the importance of certain infrastructures. Artisans who produced goods from start to finish became workers specialising in tasks along an assembly line, who then were replaced by robots that took over routine tasks whilst workers monitor and maintain the system. Similarly, waterways gave way to railroads, which in turn were superseded by motorways. These changes disrupt the lives of people and whole regions but they also produce huge gains as more can be produced with fewer resources and more places gain access to the knowledge and capacities that leading places within and across countries have.

Disrupting the way economies function might be more important now than it has ever been before. Disruptive innovations might be the only way to tackle “grand” societal challenges OECD countries are facing. Without significant changes to transport, energy production and a move towards less wasteful consumption, climate mitigation efforts and the transition towards carbon-neutral economies will fail. In many areas, innovations are becoming increasingly disruptive, completely moving markets away from existing practices introducing new paradigms and opening up avenues for further developments.

Whether through the effect of a combination of different innovations or individual disruptive innovations, new opportunities come along with the displacement of existing industries, workers and respective institutions. Innovation can have very different regional impacts. It can disrupt incumbent industries in all types of regions but the most developed regions in the innovation frontier are more likely to create (and benefit the most from) disruptive technologies, finding new sources of jobs and growth paths. If regions behind the frontier cannot benefit from new opportunities related to industrial transitions and disruptive technologies, they can face prolonged unemployment due to automation.

This chapter first considers the impact of industrial revolutions on regions and identifies levers that regions can and have used to manage transitions of their economies. It then outlines the notion of "disruptive technologies" and describes strategies that regions can use to prepare for and manage their potential challenges.

This chapter and the full report draw from a series of expert workshops on "What works in innovation policy? New insights for regions and cities" organised by the OECD and the European Commission (EC). For each workshop, experts provided background papers that, together with the discussion during the workshop, form the basis for this report:

- Fostering innovation in less-developed regions, with papers by Slavo Radošević (2018[5]) and Lena Tsipouri (2018[6]).
- Building, embedding and reshaping global value chains (GVCs), with papers by Riccardo Crescenzi and Oliver Harman (2018[7]) and Sandrine Labory and Patrizio Bianchi (2018[8]).
- Developing strategies for industrial transition, with papers by David Audretsch (2018[9]) and Charles Wessner and Thomas Howell (2018[10]).
- Managing disruptive technologies, with papers by Pantelis Koutroumpis and François Lafond (2018[11]) and Jennifer Clark (2018[12]).
- Experimental governance with papers, by Kevin Morgan (2018[13]) and David Wolfe (2018[14]).

Paths for transition in regional economies

Innovation and innovation policy are central to ensure that regions transition from their current strengths towards new opportunities. The lessons from past industrial revolutions show that transitions are no mean feat. Even today, many European and OECD regions appear to be stuck in a "middle-income trap" (EC, 2017[15]; OECD, 2018[16]). These regions were once drivers of growth in their countries but lost momentum through the changing nature of manufacturing, the shift in mining production out of more affluent OECD regions and the rise of new (tradeable) service sectors.

Managing industrial transitions requires identifying and exploring areas of economic potential to generate new sources of regional growth. The identification of domains of competitive advantage should not be limited to the public sector. It requires engaging with the private sector, academia, as well as relevant actors from civil society. This "quadruple helix" approach is not new: the triple helix of government, private sector and academia was formalised in the early 1990s (Etzkowitz and Leydesdorff, 1995[17]) and even the addition of civil society as a fourth helix has been discussed for over 15 years (Liljemark, 2004[18]). There is, however, no consensus on how the approach can be operationalised in different regional contexts (e.g. for regions where governmental capacity is low), across levels of government or how continuous learning and improvement can be embedded in the process (see Chapter 5).

There is no unique path to success when it comes to economic transitions. Policy can build on a growing body of evidence that considers a wide range of regional settings. The applicability still requires a thorough assessment of the local assets in a region. The central question for economic transition is "where to?". Diverging success stories of Los Angeles and San Francisco (see also Chapter 5) and industrial policies that aimed at "picking winners" but failed to stir innovation (Dutz et al., 2014[19]) show how difficult it is for policy to set the right objectives and incentives.

The core question is whether it is better to specialise in those areas where a region is already strong or whether it is better to diversify. More specialised regions tend to be richer (in term of per capita gross domestic product [GDP]) but more diversified regions grew faster during the 2008-14 period (OECD, 2018[16]). Even if regions aim to diversify, the identification of suitable sectors and strategies to develop activity within these sectors is far from straightforward. In places with a well-diversified and vibrant economy, gaps might be easier to identify. The city of New York, for example, identified a lack of capacity in training engineers, in particular relative to tech-hubs around Boston and San Francisco, as a barrier to diversifying its economy. The result was the creation of a new graduate university "Cornell Tech" with a campus on Roosevelt Island (Katz and Bradley, 2013[20]). In places with a less diversified economic base and production that is focused on the extraction of raw materials, agriculture or low-tech manufacturing, the potential for diversification is much greater; but that also means it is harder to develop a concrete strategy (Balland et al., 2019[21]).

Specialisation and diversification of regional economies

The sectors and types of regional entrepreneurial activity will determine regional innovation paths. Three common pathways for regions' innovation development include: i) regional specialisation in a particular technology domain; ii) regional diversification in related technological domains; or iii) regional diversification in unrelated technological domains (Table 3.1). The common factor to each innovation path is the need for entrepreneurship discovering and exploiting opportunities to create value within each path, whether improving existing products or services, or creating new ones (related or unrelated with the regions' technological base).

Table 3.1. Stylised regional innovation and economic development paths

Different regional development paths explored through innovative entrepreneurship

Innovation development path	Definition	Opportunities	Challenges
Specialisation	The region increasingly develops its economic activity around one main sector.	Extensive exploration of economies of scale and scope.	Innovation is incremental, consisting mostly of smaller improvements. Lower resilience to shocks affecting the sector of specialisation.
Related varieties	Region branches into different sectors that share common features, such as similar knowledge and skills requirements.	Capacity to find new growth paths if one particular sector is negatively affected. Margin to explore scale and scope economies in the areas of sectoral "relatedness".	Not likely to enable the most impactful innovations, which require re-combinations of unrelated and distant types of knowledge.
Unrelated varieties	Region branches into a number of unrelated sectors.	More prone to develop successful radical technologies. Appropriate for the 4th industrial transition as artificial intelligence (AI) and connectivity enable cross-sectoral synergies. More resilient to shocks that affect negatively one sector.	Requires open innovation system and technological experimentation. High risk of technological failure.

Regional specialisation or regional diversification?

Specialisation of regional economies in certain sectors points towards comparative advantages. Strong sectors are the result of some form of local advantage, albeit this advantage might have eroded over time. Further developing the area of specialisation comes with concrete advantages. The skillset of the local workforce remains relevant, firms can incrementally move towards new fields without major disruptions and the risk of engaging in related activities is relatively limited. Once a competitive advantage is found, new opportunities emerge for local firms to further improve that field of knowledge (Boschma, 2004[22]). Many regions specialise in particular sectors and successfully innovate and grow for long periods of time by incrementally improving within existing sectors. They are thereby "extending" or "upgrading" their industrial development path (Grillitsch, Asheim and Trippl, 2018[23]).

An economy is "specialised" if a small number of sectors account for a relatively large share of its GDP, whereas it is "diversified" if each of a relatively high number of sectors accounts for a small share of GDP. Two examples for highly specialised (and successful) regional economies are the mid-sized cities of Erlangen and Wolfsburg in Germany. Volkswagen employed 60 000 workers at its seat in Wolfsburg, compared to a total working-age population in the municipality of 77 000. The "campus" of Siemens in Erlangen had about 25 000 employees compared to a total working-age population of about 71 000 (The Economist, 2016[24]). Examples are not limited to Germany but smaller cities and rural areas often have to rely on specialisation as they lack the critical mass to build strength in many sectors (OECD, 2016[25]).

A distinction is necessary between specialisation in growing and dynamic industries, and specialisation in mature and declining industries. Like Wolfsburg, the city of Detroit in the United States was heavily invested in its automobile industry, leading to its nickname "Motor City". But the sector failed to sustain growth through the third industrial revolution. In the fourth industrial revolution, regions specialised in industries relying on routine tasks are likely to experience more disruption from automation. Too much specialisation in one or a few mature industries relevant in past industrial transitions can expose regions to negative shocks affecting those industries (Storper et al., 2016[26]). Regional specialisation affects the patterns of risk of automation among metropolitan areas in the United States. Between one-half and three-quarters of workers in metropolitan areas may face severe disruption in the near future (Frank et al., 2018[27]). The risk decreases with the size of the city, in part because larger cities have a higher share of employment in occupations whose tasks are more resilient to automation.

Excessive specialisation can affect regions' innovation capacity negatively, since innovating within the same mature sector consists mostly of incremental innovations producing small improvements. This can lead to persistent economic slowdowns if regions find themselves incapable of adapting their industrial base to explore other opportunities, which is the case when the impact is a complete industrial transformation (Schoenmakers and Duysters, 2010[28]). But overcoming excessive specialisation can be difficult.

The mining industry in Pittsburgh (United States) was essential for the development of the city but contributed to crowd out entrepreneurship in the region (Chinitz, 1961[29]). Rochester (United States) provides another example of excessive specialisation. In 1879, when the emulsion-coating machine was invented in Rochester, the city of New York was the centre of the photographic industry. The Eastman Kodak Company in Rochester soon took over the market for photographic film and Rochester replaced New York City as the leading location in film production, becoming highly specialised in that sector. In the 1960s, Kodak was the largest employer in Rochester with over 60 000 employees. Yet, Kodak did not manage the disruption of digital technologies, nor did the region. When the company shut down its largest research and production facility, the population of Rochester witnessed a decline of the entire region. As Kodak's workforce dropped by almost 80% between 1993 and 2006, the whole region rapidly lost population (citi, 2016[30]).

Linking existing strengths with new ones through "related varieties"

Instead of further specialising within existing sectors, regions can aim to diversify their economies and thereby "branch" onto new development paths. Regions with more diversified economies can be better positioned to enable the recombination of existing knowledge pieces to find new growth strategies. Knowledge spillovers between different sectors within a region are an important source of innovation. A diversified regional economy can be more likely to innovate and create new growth paths (Henderson, Kuncoro and Turner, 1995[31]; Rosenthal and Strange, 2004[32]). At the heart of such innovative capacity is the creation of inventions that introduce novel technological approaches, recombining technologies in new ways (Arthur, 2009[33]). Knowledge from multiple sectors can be exchanged more easily when the distance between sectors in a region is not too large. Sectors need to be related or complementary, presenting low co-ordination costs of combining different types of knowledge (Frenken, Van Oort and Verburg, 2007[34]).

A strategy to identify and foster new paths that link with existing assets is diversification into "related varieties". The "related varieties" approach maps the presence of specific sectors or products ("varieties") in different countries and regions. This mapping can then be used to identify varieties that tend to co-locate, i.e. "related" variety. The idea is that the local assets in existing sectors or capacities to produce current products are easier to bridge to those required for related varieties. A growing literature has shown that the probability that a region will start exporting a new product (Hidalgo et al., 2007[35]; Hausmann et al., 2014[36]) or start patenting in a new technology field (Boschma, Balland and Kogler, 2014[37]; Petralia, Balland and Morrison, 2017[38]) increases with the number of related activities present in that location. A positive link between related diversification and economic performance, in general, has been found in several empirical studies (Content and Frenken, 2016[39]).

The concept of "related variety" as regional development path is consistent with the reality at the firm level, where diversified firms providing a related variety of products tend to outperform specialised firms. For example, companies in the energy sector require a broad range of goods and services, so an intermediary firm can sell drilling equipment, well completion services or environmental management instruments, for example, through three separate but related business units. In a single visit, sales staff can offer multiple products and services to clients, yielding marketing economies of scope, with the potential to outperform competitors, which only offer a single product or service.

An additional example of firm-level activity benefitting from relatedness is research and development (R&D). If a firm has different, but related business units, all can potentially benefit from inventions resulting from R&D activities. Sharing common R&D activities and manufacturing facilities enables to distribute common fixed costs across more revenue streams (Palich, Cardinal and Miller, 2000[40]). Pursuing related-variety diversification strategies are limited by the co-ordination costs of combining multiple product lines. A study on US equipment manufacturers finds that producers favour related diversification in their products if the potential synergies (e.g. in terms of shared inputs) but that this positive effect is attenuated if existing products have complex value chains (Zhou, 2010[41]).

Related variety fulfils two needs at the same time: diversity and relatedness. Some degree of proximity in terms of common costs, technologies, skills and knowledge (that is, relatedness between sectors) is required to ensure that synergies, effective communication and interactive learning between sectors take place at low co-ordination costs. However, some degree of distance (that is, variety between sectors) is needed to avoid cognitive lock-in and to stimulate novelty. Boschma (2009[42]) provides the example of Emilia Romagna in Italy as a case of the branching process in related varieties. Many successful sectors in the region, such as ceramic tiles, the packaging industry and robotics, emerged out of a pervasive regional knowledge base in engineering. These sectors not only built and expanded on this extensive knowledge base, they also renewed and broadened the regional economy of Emilia Romagna.

The "related varieties" approach works best for regions that aim to follow established developments paths into new sectors. The identification of what sectors or products are related relies on precedents set in other places. This means that varieties might seem unrelated given the available data but might actually be closely related. This shortcoming is particularly important for innovation policy, where the explicit focus is on novel approaches. It might be the innovative activity itself that creates links between seemingly unrelated sectors or products.

Big push towards "unrelated varieties"?

In some regions, the transition towards new sectors constitutes a more radical shift. Conceptually these regions move towards "unrelated varieties", i.e. sectors or products that are not typically associated with the industrial structure of the region. The move from agricultural to industry-based economies is one such move that many regions have successfully taken. Radical innovations have the potential to connect previously unrelated knowledge bases and create new industries connected in a "related variety" fashion. For example, in the 19th century, the invention of synthetic dyestuffs gave birth to new related industries, as pharmaceutics, explosives, plastics, synthetic fibres and photography, all centred on the same new core technology (Malerba and Orsenigo, 2006[43]).

North Carolina in the United States is a successful example of branching through unrelated varieties. During the second industrial transition, North Carolina ranked as the poorest state in the United States (Link, 1995[44]), with its three main sectors being textiles, furniture and tobacco. However, during the third industrial transition, the region became one of the most innovative and prosperous regions in the world. North Carolina successfully branched into new high-growth sectors: IT, pharmaceuticals, banking, food processing and vehicle parts (Walden, 2008[45]). At the centre of this success was an innovation policy creating North Carolina's Research Triangle between the counties of Chapel Hill, Durham and Raleigh and their universities campuses. Within the Research Triangle lies one of the most prominent science and technology parks, the Research Triangle Park, that played a key role in the transformation (see also Box 3.7).

The growth "miracle" of South Korea that took the country from "developing country" status in the early 1960s into the group of "high-income countries" in mere decades,[1] is another dominant example of a "big push" towards new sectors. Targeted interventions by the central government promoted the development of competitive export-oriented sectors and those newly developing sectors that the government deemed worthy of promotion (Pack and Westphal, 1986[46]). As in the example of North Carolina, the knowledge base – here in the form of a well-educated labour force relative to the capital endowment in Korea – played an essential role in complementing the industrial policy and accompanying reforms (Rodrik, Grossman and Norman, 1995[47]). The Korean strategy is not without risk. Today, the legacy of the past interventionist policies impede progress towards fully transitioning the Korean economy (OECD, 2018[48]).

To adapt its economy to the fourth industrial revolution, Korea has changed its strategy. In 2014, the Centers for Creative Economy and Innovation (CCEIs) were created. In each of the 17 regions that house a CCEI, the centres link with existing strengths and the corporate fabric to push the local economy to the next stage. The approach focuses on linking research centres with entrepreneurship (Box 3.1). Having a dynamic regional entrepreneurial ecosystem contributes to the development of disruptive innovations because young firms are more likely to introduce disruptions. Large corporations can utilise this model for open innovation through CCEIs. Open innovation for those large incumbents will be crucial for success.

The most radical technological and scientific discoveries tend to combine knowledge pieces that were never combined before. Firms and inventors in regions that are diversified in unrelated sectors can find more opportunities to innovate by recombining unrelated pieces of knowledge. Such regions are likely to be in the scientific and technological frontier, with high innovation capacity for technological experimentation. Additionally, such knowledge pieces are more unrelated or distant, being more difficult to combine (Uzzi et al., 2013[49]; Wang, Veugelers and Stephan, 2017[50]). The recombination of unrelated knowledge pieces is also riskier: some generate the most impactful breakthroughs but many tend to fail.

In addition to being riskier, these radical technological and scientific discoveries can also be costlier, requiring a longer time to develop commercial applications.

Box 3.1. Centers for Creative Economy and Innovation, Korea

CCEIs in Korea were established in 2014 with the objective of supporting the creation of new industries and markets, functioning as a pivot for start-up incubation, small business innovation and regionally specialised programmes. The CCEI has 19 field offices covering 18 Korean regions and each focuses on promoting local entrepreneurship in line with regional industry characteristics and competencies of large regional corporations, fostering complementarities between incumbents and potential start-ups.

The centres promote partnerships and knowledge transfer between large Korean corporations and young firms. Additional services are provided, such as specialised consulting, according to the opportunities and challenges of each region. Consulting goes beyond technological considerations, covering strategic management skills, finance, marketing or R&D procedures for example. By providing specialised consulting along with facilitating partnerships with larger corporations, the CCEI supports young firms to start-up and scale-up using the networks of established corporations in order to grow faster and achieve global scale.

Source: CCEI (n.d.[51]), *Introduction of Innovation Center*, https://ccei.creativekorea.or.kr/eng/center/info.do.

Relatedness is more important for innovation in regions with a weaker innovation capacity. Xiao, Boschma and Andersson (2018[52]) find the effect of relatedness to decrease as regional innovation capacity increases. By focusing on exports, Saviotti and Frenken (2008[53]) find a related export variety to be linked with short-term gains in regional GDP per capita growth and productivity, while unrelated export variety promotes growth with a considerable time lag. They argue that related variety means knowledge is easily recombined in new products, causing direct growth effects, while unrelated variety, though harder to recombine, can, if successful, lead to completely new industries sustaining long-term growth.

Drawing on knowledge and resources residing in other regions can facilitate new growth paths through new and unrelated knowledge combinations, Multinationals, immigrant entrepreneurs and mobile scientists are examples of potential sources of external knowledge (Neffke et al., 2018[54]). In the context of the fourth industrial revolution, technologies such as artificial intelligence (AI) and machine learning can facilitate integration across a broad range of industries and types of economic activity. Thus, regions with a wide sectoral diversification can be better positioned to explore synergies and innovate across the fringes of different technologies and industries.

Regions, industrial revolutions and disruptive innovations

Often the gradual pace of substantial industrial change is misinterpreted as a temporary loss of competitiveness. The decline, for example, of Pittsburgh's steel industry or Acron's tire manufacturing (in the United States) was more than that. They were a symptom of a substantial change in the way industries are structured and production processes are functioning. Since the onset of modern production – the first industrial revolution – economies have undergone two further major revolutions and are currently taking the first steps in what will be the fourth industrial revolution.

Four industrial revolutions

Box 3.2. Past and current industrial revolutions

The first industrial revolution started in Great Britain in the late 18th century with the mechanisation of the textile industry and the introduction and spread of the steam engine, which in turn facilitated the development of manufacturing in factories. In the following decades, the use of machines to manufacture goods, instead of crafting them by hand, spread around the world.

By the mid-19th century, the second industrial revolution began with a broad range of technological inventions that gave rise to assembly line manufacturing, enabling mass production. Along with the emergence of large-scale manufacturing also came a deskilling of labour, as tasks became routinised and simplified. The enhanced specialisation made a greater division-of-labour and greater focus of each specific task on the assembly line possible.

The third industrial revolution came with the introduction, development and diffusion of the computer. The key inventions, beginning around 1970 and continuing through the remainder of the century, were also the personal computer, semiconductor, Internet and Web 2.0. Like its two earlier predecessors, the third industrial transition had a large impact on virtually all aspects of society. It led to a massive shift in the occupational structure of the labour force, resulting in individual winners and losers based on occupations, and had strong impacts on the prosperity of cities and regions.

The fourth industrial revolution is being fostered by a new wave of innovations and technological advances, with AI and connectivity at the heart of this new wave of technological change. Digitisation in manufacturing is having a disruptive effect in every industry, such as office equipment, telecommunications, photography, music, publishing and films. The effects will not be confined to large manufacturers, as these technological advancements are empowering small- and medium-sized enterprises (SMEs) and individual entrepreneurs.

Structural change in the industrial fabric happens gradually and often imperceptibly. It is often only recognised as a major event after reaching a critical level. Change in the structure of a region’s core companies affects employment in their sector. As these firms are connected to other firms in the region through supply and demand links and often constitute a key pillar of the regional innovation system, many (if not all) other firms in a region are affected by major changes. Examples in Europe that underwent a strong decline due to industrial structural change include regions such as the Ruhr area (steel, mining, machines) in Germany, or Newcastle upon Tyne (mining, steel, shipbuilding) in the United Kingdom. Emblematic examples in the United States include the decline of Kodak and its impact on the region of Rochester and the decline of Detroit’s automobile industry in Michigan. These major events are caused by a latent industrial structural change and have strong spatial repercussions, especially when regions are too reliant on those industrial sectors.

Source: Adapted from Audretsch, D. (2018[9]), “Developing strategies for industrial transition”, Background Report for an OECD/EC Workshop Series on Broadening Innovation Policy: New Insights for Regions and Cities, OECD, 15 October 2018, Paris.

The catalyst for each industrial revolution was a decidedly different and unique set of technologies. Ranging from steam in the first industrial revolution to transportation technologies and electricity in the second industrial revolution, computers, semiconductors and the Internet in the third. Finally, the current, fourth industrial revolution, is likely driven by the digitalisation of services and the development of AI and machine learning supported by automated exchanges between machines, the Internet of Things (IoT) (Box 3.2).

Economic history is replete with dramatic changes in economic structures at the regional, national and international levels. In the last two centuries, techno-industrial leadership shifted from Great Britain to Germany and the United States, and some countries in Southeast Asia have joined the ranks of leading industrial countries. Regions are subject to similar shifts, as the cases of Belgium, Germany and Great Britain demonstrate. Their core industrial areas have lost their economic dominance and have been replaced by a set of new growth regions in South East England, Flanders and the South of Germany respectively (Boschma, 2009[42]). In order to sustain long-term regional development, regions must constantly transform and renew their economic base (Martin and Sunley, 2008[55]).

The catalyst for the first two industrial revolutions were inventions that fundamentally changed the capacity to combine new tools and machines with natural resources that led to an unprecedented gain in productivity. Much more could be produced and distributed within a shorter period of time and significantly less need for human labour. The locational advantage of regions that helped attract capital investment was typically linked to an abundance of key natural resources. Investment was the main driver for economic performance.

At the beginning of the third industrial revolution, established manufacturing companies tried to adapt their traditional production formulas. The "just in time" production principle was the result. With the rise of the computer era, the key factors and resources that facilitated growth shifted from physical capital to knowledge, ideas, creativity, skills and human capital. This was partly due to the high component of human capital in the production or development of computers within the industry. The computer industry ranks among the most intensive users of human capital and R&D. Beyond the production of computers, the main beneficiaries of using computers at work were also workers with higher levels of education and "human capital". Economists refer to "skill-biased technological change" that summarises the complementarity between human capital and using computerised technologies.

The first two industrial revolutions raised the demand for workers with low levels of skills, while in the third, the complementarities between computers and human capital resulted in an increased demand for human capital (Acemoglu, 2003[56]; Autor, Levy and Murnane, 2003[57]). The fourth industrial revolution is likely to continue to rely on similar factors and resources as the third but the relevance of these factors is likely to increase the importance of human capital (Frey and Osborne, 2017[58]). Box 3.3 defines the key elements typically associated with the fourth industrial transition.

Box 3.3. What is the fourth industrial revolution?

The fourth industrial revolution is still ongoing and its defining characteristics will only become evident after its resolution. There are, however, some elements that appear to drive current radical change. For this industrial revolution, it is the integration of the physical and digital worlds. The digitalisation of manufacturing transforms conventional manufacturing into "smart factories". A key salient feature of the transition is machine communication, not just between humans and machines but also machine-to-machine. With extensions into artificial intelligence (AI), connectivity through IoT and flexible automation enabled by combining the two (WEF, 2018[59]).

The first set of enabling factors of the current industrial revolution is the combination of advances in computing power and the availability of big data, which are allowing AI algorithms to excel. AI is enabling event recognition and the translation of such recognition for automated decision-making. Speech and image recognition have already reached the accuracy of the human brain. AI is becoming the key enabling feature of progress, from self-driving cars and drones to virtual assistants and translation software. R&D have made impressive progress, from software used to discover new drugs to algorithms that predict tastes and cultural interests (Schwab, 2017[60]). AI can also contribute to the creation of entirely new industries, based on scientific breakthroughs in the same way as the discovery of recombinant DNA technology led to a revolution in industrial biotechnology and the creation of vast economic value (OECD, 2018[61]).

A second enabling factor of the current industrial revolution involves the level of connectivity enabled by IoT. The miniaturisation of computers enables them to be attached to individual machines and then connected to the Internet. Sensors detect and report information online about machine operations. One example involves farm production, where sensors for temperature, water content and soil quality relay instantaneous information and feedback to the tractor operator about how to optimally adjust the planting procedure. Each sensor connects not just with each other but also larger systems in what constitutes IoT (EC, 2017[62]).

The combination of AI and connectivity can enhance productivity in factories. AI helps minimise interfaces with humans and, instead, production relies on the feedback and reactions that follow optimisation based on autonomous machine learning. For example, in aerospace, Airbus deployed AI to identify patterns in production problems when building its new A350 aircraft. A worker might encounter a difficulty that has not been seen before but the AI, analysing a mass of contextual information, might recognise a similar problem from other shifts or processes. Because AI immediately recommends how to solve production problems, the time required to address disruptions has been cut by one-third (Ransbotham et al., 2017[63]). More data from sensors and systems based on the IoT enhances the ability to make smarter decisions and ultimately boost both machine and system efficiency.

Source: WEF (2018[59]), "The next economic growth engine: Scaling fourth industrial revolution technologies in production", White Papers, World Economic Forum, https://www.weforum.org/whitepapers/the-next-economic-growth-engine-scaling-fourth-industrial-revolution-technologies-in-production (accessed on 20 November 2018); Schwab, K. (2017[60]), *The Fourth Industrial Revolution*, Crown Publishing, New York; OECD (2018[61]), *OECD Science, Technology and Innovation Outlook 2018: Adapting to Technological and Societal Disruption*, https://dx.doi.org/10.1787/sti_in_outlook-2018-en; EC (2017[62]), "Industry 4.0 in agriculture: Focus on IoT aspects", https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Agriculture%204.0%20IoT%20v1.pdf (accessed on 27 November 2018); Ransbotham, S. et al. (2017[63]), "Reshaping business with artificial intelligence: Closing the gap between ambition and action", https://sloanreview.mit.edu/projects/reshaping-business-with-artificial-intelligence/ (accessed on 21 November 2018).

Disruptive innovation

Not all disruptive innovations trigger an industrial revolution but they disrupt part of the economic fabric in countries and their regions. Industrial revolutions are driven by a combination of several technological developments that affect regions through a continued period but a single disruptive innovation has the potential to disrupt regions immediately. Today, disruptive innovations are increasingly of larger scope, scale and faster speed, in large part due to the development of digital technologies.

Defining disruption

A possible framework to characterise innovations is in terms of their level of performance improvement compared to established solutions and in terms of their impact on incumbent players in the industry. Radical innovations are those that lead to larger performance improvement, and disruptive innovation those that have high levels of impact on incumbent agents. Disruptive innovations create entirely new markets and displace existing ones while sustaining innovations improve existing markets developing current products or services (Christensen, 1997[64]).

Disruptive innovation describes a process in which new entrants challenge incumbent firms, often despite inferior resources. This may happen in two ways: i) entrants may target over-looked segments of the market with a product considered inferior by incumbent's customers and later move upmarket as their product improves; and ii) they may create entirely new markets turning non-consumers into consumers.

Often incumbents fail to identify new opportunities or do not have incentives to explore them as they can cannibalise existing products or services. Incumbent firms are better placed than young firms to pursue sustaining innovations (in contrast to disruptive). Sustaining innovations enable incumbents to reach higher profit margins with their existing products or services. Incumbents have high incentives to compete for sustaining innovations and they have larger resources to win.

Disruptive innovation is a different concept from radical innovation, i.e. the degree to which the innovation differs from existing practices, goods or services. Innovations can be both disruptive and radical (see Table 3.2 for examples). Being able to distinguish radicality and disruption is important in order for regions to better manage different types of innovations as the local economy needs to adapt differently to each type. In particular, the degree to which incumbents are affected differs by the degree of disruption, even when innovation is incremental.

Table 3.2. Examples of innovative products and services by the degree of disruption or radicalness

	Sustaining innovation	Disruptive innovation
Radical innovation	Electronic cash registers were a radical but sustaining innovation relative to electromechanical cash registers, whose market was dominated in the United States by National Cash Register (NCR). NCR missed the advent of the new technology in the 1970s so that NCR's product sales dropped to zero. Electronic registers were so superior that there was no reason to buy an electromechanical product – a technological leapfrog within the same product space. Yet NCR survived on service revenues and easily introduced its own electronic cash register. With extensive sales organisation expertise, NCR quickly captured the same share of the market it enjoyed in the electromechanical realm.	When Netflix was founded, it was the first entertainment company offering DVDs by mail and later on-demand streaming service – a radically different operating model than the traditional retail store model. Its DVD rental competitor, Blockbuster, had never considered this market outside of its retail store model. In response to the new market and business model, Blockbuster responded with its own version of the Netflix approach, but at a price that could not compete. Blockbuster had all the costs related to operating the physical stores and infrastructure that Netflix avoided. Blockbuster ended up filing for bankruptcy.
Incremental innovation	Companies in mature industries can implement little improvements to their products e.g. adopting IoT features. Nest is a company with two products on the market: a thermostat and a fire and smoke alarm. The firm is advancing these products with sensors and intelligent algorithms, which enable these devices to understand user preferences, interact more humanely and talk to similar devices to ensure incidents are reported in a more informative way. Nest's products are fundamentally doing the same thing as devices from previous generations but providing connected user experience. Competing firms can equally adopt such technologies from IoT equipment providers.	The email service provided by Google – Gmail – was not born during the pioneering days of email, nor was the first email service to go mainstream. Once it was introduced, Gmail provided exactly the same service as other email providers – sending and receiving emails – but Gmail introduced little improvements. Such minor improvements include providing more storage space for users, new functionalities such as categorising emails, integration with other services as synchronising users' calendars to the email service, or even small mechanisms preventing people from sending "unwanted" embarrassing late-night emails for example. By providing such small improvements, Gmail disrupted existing players such as Yahoo or Hotmail, quickly becoming the dominant player in terms of market share in most OECD countries.

Source: Adapted based on Christensen, C. (1997[64]), *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Harvard Business School Press; Reinsberg, R. (2009[65]), "Netflix", https://www.technologyreview.com/s/416843/netflix/ (accessed on 10 December 2018); The Economist (2017[66]), "Who's afraid of disruption?", https://www.economist.com/business/2017/09/30/whos-afraid-of-disruption (accessed on 10 December 2018); Kishore, S. (2013[67]), *The Power of Incremental Innovation*, https://www.wired.com/insights/2013/11/the-power-of-incremental-innovation/ (accessed on 10 December 2018); Covert, A. (2014[68]), "Gmail turns 10: How Google dominated e-mail", https://money.cnn.com/2014/04/01/technology/gmail/index.html (accessed on 10 December 2018); Snyder, C. (2008[69]), "Google's mail goggles prevents drunk emailing", https://www.wired.com/2008/10/googles-mail-go/ (accessed on 10 December 2018).

Radical innovations are not instant. They result from cumulative processes of multiple inventions and innovations, and their diffusion and adaptation to different circumstances (Warnke et al., 2019[70]). Radical innovations are disruptive when they represent a technological leapfrog that disrupts incumbents or creates entirely new markets (Hopp et al., 2018[71]). Innovation is both radical and "sustaining" when it is a remarkable improvement in existing markets that does not disrupt incumbents. Incremental innovations, in contrast to radical, only represent small improvements. Incremental innovations can be disruptive when small improvements severely disrupt incumbents or sustaining when they just provide minor developments of existing products or services.

Identifying disruptive innovations

Based on the market-related definition, disruptions are only identifiable "post mortem", when the adverse effects on incumbents are already evident. A consistent framework to identify potential for disruption *ex ante* can help regional policymakers prepare for the challenges of disruption as well as explore potential opportunities.

Technological foresight exercises are therefore important for regions, as they create absorptive capacity by increasing local understanding and awareness about possible challenges and opportunities arising from future technological developments. Different technologies have heterogeneous impacts on regions; thus, equipping local agents with the tools that help them predict how specific technologies can affect them is particularly important since there is no one size fit all prescription for successful prediction.

Perhaps the earliest tool of quantitative technology forecasting is trend extrapolation, which consists of expecting new technologies to follow the same behaviour in terms of growth as previous technologies. However, trend extrapolation has major drawbacks. They rely heavily on the continuation of existing trends and, as a result, may not always be appropriate when attempting to construct scenarios for the very long run about technological disruption. For radical and disruptive technologies, especially digital technologies, there also appears to be a "holy cow" moment where progress is made at an exponential pace after a long run-up of slow progress (Baldwin, 2019[72]). Machine learning is an example of a technology where decades worth of theoretical work are resulting in massive payoffs in terms of practical progress within a few years.

A complementary approach that has been historically popular is to leverage experts' opinions. One such approach is the Delphi method, originally developed by the RAND Corporation in the 1950s.[2] The method follows an iterative approach that asks experts to forecast events and to update their forecasts after receiving the aggregate results of all experts' views from the previous round. Delphi aims to use the wisdom of crowds in repeated interactions while avoiding bias from concerns about a reputational effect. Advances in behavioural economics and psychology are providing further was of "debiasing" expert opinions (Koutroumpis and Lafond, 2018[11]).[3] Questions remain whether expert opinion actually outperforms the predictions by a random group of individuals, e.g. experts' fame has been found to be negatively associated with the accuracy of their predictions in political science. Selecting the right experts is, therefore, a critical and difficult part of the process as well (Tetlock and Gardner, 2016[73]).

"Prediction markets" use pecuniary incentives to elicit (informed) views from many forecasters. They allow individuals to trade on future events, i.e. to "put their money where their mouth is". The difficulty with implementing such markets is to delineate between gambling (and accordingly gambling regulation) and prediction markets. The quality of the information that prediction markets provide is still a matter of research as well and subject to a complex interaction between the availability of external information and the experience of participating individuals (Brown, Reade and Vaughan Williams, 2019[74]).

The combination of machine learning techniques and "big data" opens up new avenues for forecasting. Patent data has been used in some recent applications, to map patent data as innovation networks for predictive purposes for example (Acemoglu, Akcigit and Kerr, 2016[75]). The network is constructed using citation data and the results show that levels of patenting activity predicted using activity in an upstream (cited) category is correlated with actual patenting in the future. A second approach starts from the idea that innovation networks are in a sense too static because the number of nodes (technological domains) is given, whereas it seems important to try to predict radically new domains. This approach considers new technological categories in patents and aims to identify patterns to predict their emergence (Koutroumpis and Lafond, 2018[11]).

Big bang disruptions

Developments in digital technologies are enabling a new form of extreme disruption. Disruptors are typically considered as new entrants, spotting opportunities in lower ends of traditional market spaces or addressing types of demand ignored by incumbents, and disrupting thereafter by upgrading their value proposition (Christensen, 1997[64]). "Big Bang Disruption" – a concept proposed by Downes and Nunes (2013[76]) – is a new kind of disruptive innovation. "Big Bang Disruptors" provide better and cheaper products or services at a global scale from the moment of creation, instead of entering a market with an inferior product than those of established incumbents.

Disruptions can severely hit regions due to their level and speed of impact on incumbent firms and the speed of such impact. Big Bang Disruptors can destabilise mature industries in record time, in great part enabled by digital technologies such as broadband networks, cloud-based computing and increasingly powerful and ubiquitous mobile devices. The accelerating pace of Big Bang Disruption is driven by core technologies that became better and cheaper. The most familiar of these exponential technologies is the computer processor that has continually become faster, cheaper and smaller. A new generation of exponential technologies is emerging in fields such as chemistry, optics, materials and energy, promising to destabilise mature industries and their regions (Accenture, 2013[77]).

Developments in digital technologies are reducing barriers to entry by driving down entry costs for new entrepreneurs. Digital technologies are driving down the core costs of developing new products and services, such as the cost of innovation activities, of accessing information and of experimentation (Downes and Nunes, 2013[76]). These three driving forces are further explained:

- *Declining cost of creation*: Steep declines in the cost of key input materials, including computer hardware and software, along with increasingly efficient supply chains, enables innovators to provide new or better solutions than existing ones. Products and services can begin life with higher quality, at a lower price and more easily customised than those of traditional competitors.
- *Declining cost of information*: As social networks, microblogging and independent review services proliferate, consumers have easy access to more market information. Customers can discover and adopt new successful products and services much more rapidly across every traditional segment. Innovators no longer need to cultivate "early adopters" to establish new markets.
- *Declining cost of experimentation*: Due to global broadband networks and ubiquitous computing devices, innovators and users are increasingly connected in an environment optimised for collaboration. New products and services often begin life as simple combinations of existing components, tested with little cost or risk directly on the market with real consumers.

An example of digital disruption with a large regional component is the blockchain. The technology is a database that allows the transfer of value within computer networks, facilitating the shared understanding of value attached to specific data and thus allows for transactions to be carried out (see Box 3.4).

Box 3.4. Blockchain as a disruptive technology

The blockchain is a distributed database that acts as an open, shared and trusted public ledger that nobody can tamper with and that everyone can inspect. This technology may disrupt several markets by ensuring trustworthy transactions without the necessity of a third party.

Applications range from the administration of financial transactions to the creation and maintenance of trustworthy registries, or conditional transfers (smart contracts) relying on data that specify certain rules must be met before a transaction takes place. The technology can be of immense value in regions with lower institutional capacity because it provides an unfalsifiable record of transactions and ownership. Thus, it can generate improvements in transparency, efficiency and trust. Indeed, the blockchain can be a cheap platform for more efficient public services and trust in contracts. Possible uses include the registration and proof of ownership of land, business transactions, birth records, titles or pensions. A blockchain acts in this sense as a verification system of authenticity, creating permanent and secure records which cannot be distorted by corrupted activities.

The potential benefits of the blockchain are also fostering the development of innovative regulatory frameworks that enable countries and regions to fully benefit from this technology by providing a safe and transparent environment. An example of regional regulatory framework development is the "Crypto Valley" in the small Canton of Zug outside of Zurich (Switzerland). Zug put in place clear guidance as to how it would treat (blockchain-based) cryptocurrency companies and those that dealt with its assets. The new rules helped attract Ethereum, the second-biggest cryptocurrency by value, and that triggered the set-up of a new ecosystem, including law firms, tax, accounting, smart contract evolvement firms, start-ups and universities for example.

Source: OECD (n.d.[78]), *OECD Blockchain Primer*, http://www.oecd.org/finance/OECD-Blockchain-Primer.pdf (accessed 21 August 2019); Berryhill, J., T. Bourgery and A. Hanson (2018[79]), "Blockchains Unchained: Blockchain Technology and its Use in the Public Sector", https://dx.doi.org/10.1787/3c32c429-en.

Leveraging disruptive innovation in regions

Drivers and regional impacts of disruptive innovations change over time and space and from one technological domain to another. Regional characteristics interact with those of the disruptive innovation to determine how different technologies affect specific regions and what opportunities regions can derive. Broadly, there are three groups of characteristics. The first is regional assets and networks that are determined by policy and the legacy of past development. The second consists of spatial and geographical characteristics of the region and the third is the local workforce, population and prevailing culture. The list does not attempt to be comprehensive, as technologies and academic research develop the characteristics and their importance change as well.[4] For example, with constant improvements in virtual meeting technologies and progress in increasing speed and reliance of broadband Internet access, the promise of a "death of distance" allowing the replacement of face-to-face interaction and thereby reduces one of the advantages of large cities is again under discussion (Baldwin, 2016[80]).

Disruptive innovations are often seen as new products but many disruptive technologies take the form of innovative services with a strong local dimension. Health services or services related to the "sharing" economy are critical fields of disruption and very much embedded in the local area. Some technologies can be more "material" than others in their inputs and the degree to which a technology relies on tangible or intangible capital. Concretely, a new start-up in micromobility that rolls out a fleet of electric scooters in a city has the scooter as a physical component that is locally bound, but supporting services and the IT infrastructure (and algorithms) that manage the fleet are not bound to a place. The degree to which disruptive innovations are "material" in turn determines their off-shorability or territorial embeddedness. Some innovations can enable the development of an ecosystem of supporting services, or services that are themselves supported by technology. These services can represent a great share of jobs, value-added and can be knowledge-intensive and non-offshorable. While it seems difficult for policy, for instance, to change a product innovation into a service innovation, encouraging the development of associated supporting services that operate locally may sometimes be possible. In particular, the advances of AI raises concerns about the ability of regions to retain jobs and high value-added activities (OECD, 2019[81]; 2018[82]).

Some technologies cannot be implemented in the same way everywhere. Agricultural technologies are a good example of this issue, with tools, livestock and plant varieties requiring important modifications to suit local conditions. In comparison, digital technologies require little adaptation apart from language or cultural factors. Technologies that require local adaptation often diffuse and progress less fast – precisely because experience cannot be shared – but also offer more promise for regions lagging behind the frontier to engage in "technological dialogue" and develop specific capabilities to meet their own demand. The need for local adaptation is not a technological trait that can be easily influenced by policy.

What affects successful transitions in regions?

Changing benefits from the agglomeration of economic activity

The share of the global population that lives in cities has continuously increased over the last centuries. In 2015, nearly two-thirds of the people living in OECD countries lived in a functional urban area (a city and its commuting zone) with 250 000 or more inhabitants. The majority of these live in large metropolitan areas with 1.5 million or more inhabitants (39% of the total population).[5] Large cities clearly provide some benefits that attract people and outweighs the "cost" of living in big cities, such as congestion, noise, pollution and the high cost of housing that means people live in (much) smaller apartments in large cities than in rural areas (OECD, 2015[83]).

Larger cities provide a greater variety in consumption and leisure activities than smaller places. They also provide greater earnings potential for their residents. The density of cities allows workers to specialise and thereby raise their productivity and income. Density allows firms to tap into a larger and more varied pool of workers, making it easier to find the right "match" for the vacancy they want to fill. Density also allows knowledge and information to flow more easily as people can meet and exchange both formally and informally, which again raises productivity and wages. All of these factors are summarised by economists as "agglomeration economies", i.e. the pecuniary benefits that larger cities provide to their firms and residents (Duranton and Puga, 2004[84]).

The geographical concentration of innovative activities has been a common element of all first three industrial transitions. Prior to the first industrial transition, most of the population in the developed countries resided in rural regions and small towns. The inventions driving the first industrial transition facilitated the development of urban density and the emergence of cities on an unprecedented scale. From the mid-18th century onwards, thousands of people moved to the rapidly growing industrial cities of northern England, such as Leeds and Manchester, to take advantage of the opportunities that new factories and textile mills provided. The combination of job opportunities and the provision of improved infrastructure (including the Underground) allowed London to grow from 1 million inhabitants in 1800 to 3 million in 1860 and by 1900 had reached 6.5 million inhabitants (White, 2008[85]).

The English experience is not unique. In the United States, the industrial centres developed in Midwestern cities such as Detroit and Akron or Pittsburgh. In general, as countries develop and income levels rise, people flock to cities. There are no countries where increased income levels (measures in per capita GDP) have not been accompanied by a rise in urbanisation. The opposite is, however, not the case as urbanisation has not provided higher income in all countries (OECD, 2015[83]). Especially, developing countries are struggling with the move towards higher income levels despite increasing urbanisation. The difference might be linked with the drivers of income growth. Resource-intensive production in developing countries leads to urbanisation in "consumption cities" that focus on the provision of non-tradeable services to the local population, rather than "production cities" that are the hallmark of industry-led attraction of people to cities (Gollin, Jedwab and Vollrath, 2016[86]).

Cities continued to grow in the main capitalist countries over the twentieth century on the basis of manufacturing but, starting in the 1970s, many of them went through a period of deindustrialisation as jobs dispersed to low-wage regions and countries, leading in many cases to severe crisis conditions in the core. After a transitional period of slow growth in the 1970s and early 1980s, large cities in the core again experienced a strong resurgence as the 1980s passed by. Cities now found themselves at the focal point of a new "post-Fordist" economy, characterised by a decisive shift away from materials-intensive manufacturing to various kinds of high technology, management, logistical, service, design and cultural sectors (Scott and Storper, 2014[87]). Many cities have not transitioned from the manufacturing era associated with the previous industrial revolutions to the knowledge area associated with the third. As the fourth industrial revolution unfolds, such cities face the risk of a double industrial transition shock.

Geographic proximity to natural resources was a key driver of location choice in past industrial revolutions. As transport cost declined and the cost of extraction rose in developed countries, the need for colocation of resources and production disappeared. Some resources still favour local economic development. Stable and vibration-free ground soil in Wales supports the development of a cluster for the production of compound semiconductors and advanced optical instruments (OECD, 2018[16]). An abundance of cheap and "green" electricity is an important asset for heavy industrial production. More than 75% of Iceland's annual energy production is used for the production of raw aluminium.[6] Energy is the main contribution of Iceland to the production process as raw material (aluminium oxide) is imported. The sector is critical for Iceland's exports. More than one-third of the value of exports comes from raw aluminium.[7]

Whether sectors solely use the available resource for production or become part of a wider regional development strategy depends on policy choices, especially innovation policy. Iceland's cheap energy (and cold climate) have attracted a large number of data centres. Their total electricity consumption remains below the needs of the aluminium sector but is rapidly expanding. In 2013, data centres consumed 5 kWh, less than 3% of the 218 kWh used by the sector in 2016.[8] Estimates suggest further rapid expansion with 90% of the sector's electricity use driven by data centres specialising in the "mining" of cryptocurrencies (KPMG, 2018[88]). The link with other sectors is limited, as it is for the aluminium smelters that drive exports in Island. Norrbotten in Sweden has taken a different route. Using its arctic climate as a resource, the region has attracted data centres as well. The region went beyond the provision of data storage and computation services by developing itself as a testbed for machinery, construction and military equipment in cold climates through the Swedish Proving Ground Association. It also leveraged its position as an established base for satellite launching and development. The local University of Technology, based in Luleå, played a proactive and important role in promoting innovation to diversify the economic base of the region (OECD, 2017[89]).

Through the third industrial revolution, economic activity and – even more so frontier innovation – has concentrated in few metropolitan areas. In 2015, one-third of international patents were filed in only five TL2 regions.[9] Most assets associated with the knowledge economy are more spatially concentrated than people or economic activity. R&D expenditure is highly concentrated in a small number of firms (see Chapter 2). Around one-third of tertiary-educated workers are concentrated in only 20% of OECD regions (Maguire and Weber, 2017[90]). The concentration is not just evident on a global scale but also within countries, e.g. patent filings are twice as concentrated as GDP. This is true for both low patenting-intensive countries of the OECD, such as Chile or Mexico, as well as higher patenting-intensive countries such as Germany, Japan and the Netherlands.

Prominent examples of geographical concentration of computer technologies are Silicon Valley in California, Austin in Texas, or the Research Triangle in North Carolina (United States), as well as Cambridge in the United Kingdom, Munich in Germany, or Stockholm in Sweden. Because they also draw heavily on knowledge and ideas, the economic activities associated with the fourth industrial transition are likely to present geographic concentration paths similar to the third transition.

Clusters can be an important facilitator for regional innovation diffusion and cross-regional links. Policies fostering cross-cluster collaborations can link local firms to interregional value chains with the potential to benefit all organisations in the clusters being linked (see also Chapter 4). The European Strategic Cluster Partnerships for Smart Specialisation Investments consists of leveraging existing clusters as accelerators for the promotion of cross-regional links that connect different clusters (Box 3.5).

Box 3.5. European Strategic Cluster Partnerships, European Union

The overall objective of European Strategic Cluster Partnerships is to boost industrial competitiveness and investment in the EU via cross-regional co-operation and networking. Partnerships aim at facilitating co-operation across different clusters in thematic areas related to regional smart specialisation strategies.

The programme provides incentives to the collaboration of firms, especially SMEs, across regional and sectoral silos towards generating joint investment projects. The type of targeted activities ranges from preparation to implementation and investment phases of joint innovation and investments projects. Supported projects include strategy-setting and road-mapping, matchmaking activities among partners, facilitating demonstration and pilot assignments.

In its first call (2016-17), 15 cross-cluster partnerships received funding and 10 additional partnerships were on the reserve list of the call accepted to keep working on a joint co-operation agenda without direct funding. In the second call (2018-19), 25 cross-cluster partnerships received funding.

Source: EC (2019[91]), *EU Cluster Partnerships*, https://www.clustercollaboration.eu/eu-cluster-partnerships (accessed on 30 January 2019).

Breaking sectoral and spatial divides

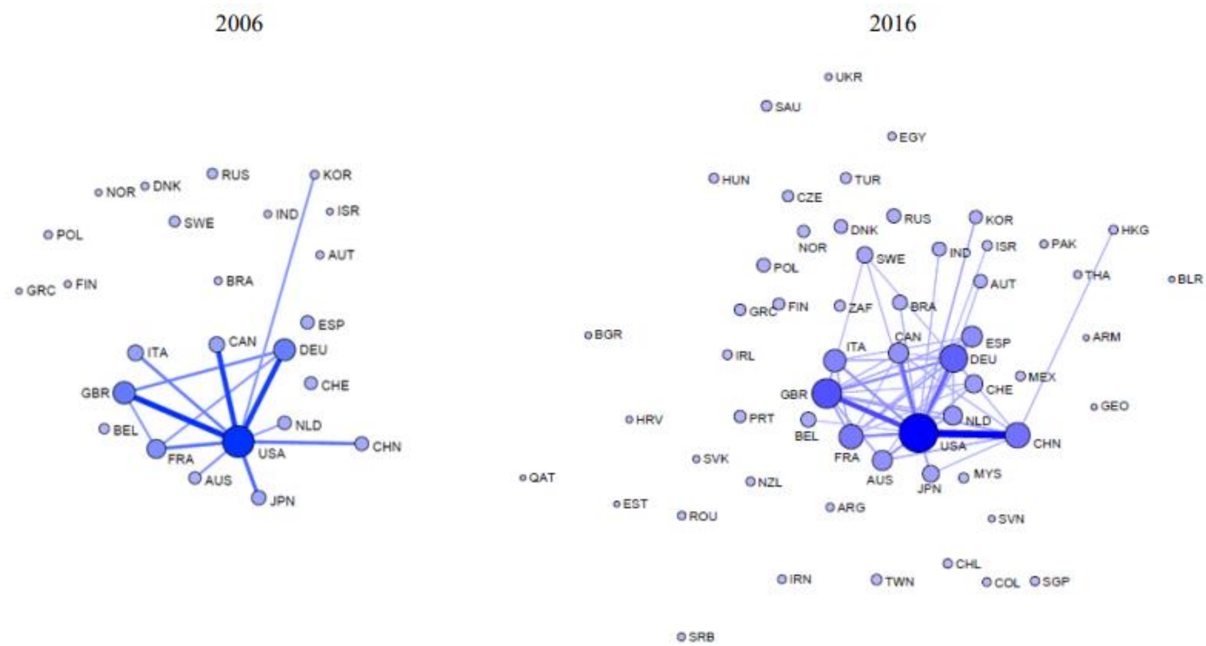
The fourth industrial revolution does not only change the speed of innovation but also the breadth of technologies involved. Innovations increasingly integrate technologies from different sectors. Digital general-purpose technologies are becoming a central element in many products and services. This means that the importance of tacit knowledge that helps link across different fields may have risen as the complexity of technologies has increased over time. It also means that the amount and sophistication of complementary investments required for technological adoption increases (Andrews, Criscuolo and Gal, 2016[92]).

Complexity is accompanied by unprecedented access to information and ease to engage in international collaborations. Through the Internet, people can access learning opportunities provided by leading research institutions and even participate in degree courses. MIT OpenCourseWare, the online learning platform of the Massachusetts Institute of Technology in the United States, provides material for 2 400 different courses to a global audience. More than half of the approximately 1.6 million monthly visitors to the website come from outside North America.[10] This growth in global reach is also evident in academic links. Compared to 2006, the number of countries with more than 10 000 academic publications has increased significantly. The number of co-authored papers, the global network of co-authors and the intensity of collaborations have increased as well (Figure 3.1).

Collaboration between larger companies and small (young) firms can help bridge sectoral divides and help manage the higher risks associated with the increasing speed of technological development. Young firms are more innovative and riskier, while established firms have deep-rooted processes, networks and larger financial capacities. Collaborative innovation partnerships enable exploiting these complementary capabilities, which have led to the advent of “project entrepreneurship” – where entrepreneurs and "intrapreneurs" create and develop new ideas inside large organisations. The speed at which firms pursue innovation activities is an important determinant for their survival (Ringel, Taylor and Zablit, 2016[93]). In a risky environment, collaborating with larger, established firms can be a valuable strategy in order to access a variety of financial and organisational resources. Similarly, established firms seeking to improve their external innovation capabilities can take advantage of the new radical ideas and energy of young firms (Box 3.6).

Figure 3.1. Academic co-authorships networks span through Asia, Europe and North America

Whole counts of internationally co-authored academic publications



Note: The position of selected economies (nodes) exceeding a minimum collaboration threshold of 10 000 documents is determined by the number of co-authored scientific documents published in 2016. Bubble sizes are proportional to the number of scientific collaborations in a given year. The thickness of the lines (edges) represents the intensity of collaboration between countries (number of co-authored documents between each pair) with a minimum threshold of 5 000 collaborations.
Source: Paunov, C. et al. (2019[94]), "How has the geographic inclusiveness of innovation evolved in the digital age? An exploration of the concentration of patenting in cities", *Science, Technology and Industry Policy Paper*, OECD Publishing, Paris, based on Scopus Custom Data, Elsevier, Version 1.2018.

Box 3.6. Collaborative innovation between young and established firms

Innovation collaborations among young firms and larger established corporations

Young firms can benefit from collaborating with larger, established firms to access a variety of financial and organisational resources. Similarly, established firms seeking to improve their innovation capabilities can take advantage of the different approaches, risk outlooks and perspectives of smaller young firms. Young, dynamic firms are often structured around the development of novel and potentially disruptive products or services, while established firms have established processes and resources, and valuable networks. Collaborative innovation partnerships can exploit these complementary capabilities.

This is not to say that potential benefits are not also balanced by obstacles that need to be overcome for collaboration to be effective (Table 3.3).

Table 3.3. Benefits and challenges for collaborations between young and established firms

Benefits for established firms	Benefits for young firms	Barriers or obstacles to collaboration
New technologies, services or products	Visibility/enhanced publicity	Speed (e.g. slow decision-making)
Brand innovation	Access to new markets	Co-ordination (e.g. changing contact points)
Fresh thinking to solve problems	Market knowledge	Culture
Increased market share and new markets	More business (e.g. increased revenues)	Contracts and negotiation (e.g. IP issues)
Rejuvenated corporate culture	Technical knowledge	Initiation (e.g. search problems)
Increase in shareholder value	Other resources (e.g. workspace)	Alignment of goals
Specialised talent and resources	Investment	Lack of access to resources
Agility to adapt more quickly to changes	Financial benefits (e.g. increased valuation)	Trust (e.g. abuse of power imbalance)

Source: Adapted from Bannerjee, S., S. Bielli and C. Haley (2016[95]), *Scaling Together: Overcoming Barriers in Corporate-startup Collaborations*, https://www.nesta.org.uk/report/scaling-together-overcoming-barriers-in-corporate-startup-collaborations/; WEF (2014[96]), *Enhancing Europe's Competitiveness Fostering Innovation-driven Entrepreneurship in Europe*, http://www3.weforum.org/docs/WEF_EuropeCompetitiveness_InnovationDrivenEntrepreneurship_Report_2014.pdf.

The value of entrepreneurship

Entrepreneurship translates innovation into regional economic rejuvenation. The prevalence of start-ups is systematically and strongly related to local employment growth across and within regions (Glaeser, Pekkala Kerr and Kerr, 2015[97]). Small (and often young) firms have greater incentive to focus on market-changing "radical" innovations than large (established) firms. Conceptually, firms have to choose between investing in improving their existing products and developing new ones. For larger firms, this incentive favours existing products more than it does in small firms as innovation in new products will "cost" part their current revenue streams (Akcigit and Kerr, 2018[98]).

Young firms, in comparison with established firms, are more prone to develop products that are new to the market and have a larger share of sales associated with the introduction of such new products. In Spain, 62% of young firms (defined here as less than 10 years old) introduced products that are new to the market, compared with 56%-58% of established firms. New products or services account for 14% of young firms' revenues, while for established firms they represent only 8%-10% (Coad, Segarra and Teruel, 2016[99]).

The growth phase of new sectors and industries is characterised by an increase in competition and innovation through new entrants. The life cycle of products and even industries exhibits typically four distinct phases – birth, growth, maturity and decline (Audretsch, 2018[9]). The birth phase characterises the development of a new market, often by few "first movers", i.e. innovating firms that establish a new product or service. The following "growth phase" is the expansion of the sector through the entry of new competitors and continued growth of the initial innovator. Growth slows down through the maturity phase as processes become routinised and firms exit the market as cost reduction in production becomes increasingly important.

The German company SAP provides a prominent example of knowledge spillover through entrepreneurship. Five IBM engineers were involved in working on developing a new product: Scientific Data Systems (SDS)/SAPE software. The company, however, did not value the potential value of the product and decided to drop the project. Convinced of its potential value, the five engineers left IBM and instead started their own firm, System Analysis and Program Development, or SAP, which became Europe's most prominent example of an entrepreneurial start-up that achieved global dominance. The investment in the new knowledge was made in one firm, IBM, but the actual innovations were realised in the context of a new entrepreneurial start-up, SAP (Audretsch and Lehmann, 2016[100])

High levels of entrepreneurial activity are also likely to characterise the fourth industrial revolution. However, the nature of entrepreneurship and the speed at which young firms can scale due to digital technologies is becoming faster. The pace of technological uptake is becoming increasingly fast: it took 30 years for electricity and 25 years for telephones to reach 10% adoption by households in the United States, but less than 5 years for tablet devices to achieve the same 10% rate. It took an additional 39 years for telephones to reach 40% penetration and further 15 before they became ubiquitous. Smartphones, on the other hand, accomplished a 40% penetration in just 10 years (DeGusta, 2012[101]). The higher speed of innovation came along with a higher risk of failure, with the examples of fast rise and fall of companies like Blackberry and Nokia being paradigmatic examples (Doz, 2017[102]; Inkpen and Himsel, 2017[103]).

The rise of digital platforms is a double-edged sword for regional development and regional innovation policies. Firms and entrepreneurs can access global knowledge and markets through digital platforms, providing opportunities to sell goods and services far beyond the local market. The small rural municipality of Fundão in Portugal decided to partner with a private company that provides intensive courses for software developers that were initially offered in Lisbon and Porto, Portugal's largest cities. Underpinning the rationale for this initiative was the ability of graduates of the intensive course to live and work from Fundão by offering their services online through digital platforms. The municipality, supported by the Centro region in which it is located, used EU funds to complement the training with the development of a Business and Shared Services Centre that hosts 14 information and communication technology (ICT) for education businesses that have created over 500 jobs, hosted 70 start-ups and over 200 privately-funded innovative projects within the first 4 years of its inception in 2013.[11] The advantage of accessing large markets through digital platforms are not limited to programmers that provide digital services but create new opportunities for a wide range of SMEs (OECD, 2019[104]).

Despite the opportunity for global access from all (connected) regions, entrepreneurial activities continue to concentrate in and around urban centres. In Europe, urban areas have an entrepreneurial advantage in terms of high-growth entrepreneurship (Bosma and Sternberg, 2014[105]). In the United States, innovative and entrepreneurial activities are typically urban-based. Technological innovation has been and remains concentrated in urban areas (Paunov et al., 2019[94]) and entrepreneurship (measured as start-up activity) has become even more concentrated in urban areas than innovation (Florida and Mellander, 2016[106]; Forman, Goldfarb and Greenstein, 2016[107]). For new start-ups, there are clusters in areas providing infrastructure (such as co-working spaces, incubators and labs) but other factors play a role for the location decision within cities as well, e.g. access to a pool of skilled workers, specialised finance and suppliers, as well as large multinationals for potential fruitful collaborations (Coll, Jové and Teruel, forthcoming). In Catalonia (Spain) the main hub for start-ups is Barcelona, with smaller cities attracting significantly fewer entrepreneurs. In Barcelona, start-ups cluster within a small number of neighbourhoods located along the east-west trunk road of the city. The same neighbourhoods also provide the highest density of local assets e.g. urban-cultural amenities, good transport accessibility, availability of talent, investors and incubators.

Another concern that is raised by the rise of digital platforms is the potential for platforms to become natural monopolies that stymy innovation. Digital platforms grow through network externalities: the more users a platform has the more interesting it is for providers and vice versa. In such a market, the platform provider can utilise their market power to extract rents that would otherwise support innovative activity. Antitrust tools and frameworks are still adapting to the new environment and might require a reassessment (OECD, 2018[108]).

Skills development was, is and will be crucial

The fourth industrial revolution has the potential to boost labour productivity but concerns abound regarding the potential impact of automation on technological unemployment and inequality. A common characteristic in all industrial transitions is that a broad range of activities that were initially labour intensive are simplified by new tools, machines or even completely replaced or automated. Technological progress and automation represent an opportunity to boost labour productivity – the key determinant of long-term economic and sustainable wage growth. However, automation displaces jobs in the short term, while new jobs enabled by the technological transition can take longer to be created and might not be created in the same place where jobs were initially displaced.

Previous waves of technological breakthroughs have shown that new technologies do not spread evenly across space and results in a variety of outcomes across regions. A common lesson is that high levels of "human capital" are a key element for regional resilience. Human capital is the summary term that economists attach to the knowledge, ability and skills that a person possesses. Equipping workers with the right human capital to give them the flexibility to exit from the industries where labour has been displaced by technology and capital and enter into industries where human skills are still needed is critical to make regions more resilient to industrial transitions (OECD, 2018[82]).

Regions with high levels of human capital are less affected by automation. With some exceptions, the risk of automation decreases as educational attainment required for the job increases. Thus, regions that have a highly educated workforce have a low share of jobs at risk of automation. The OECD (2018[82]) shows evidence of a negative relationship between the risk of automation and the share of workers with tertiary education. Regions that have the highest share of jobs at risk of automation also have the lowest share of workers with tertiary education. Reducing the risk of automation in those regions will therefore require efforts in training and education.

Human capital is more than formal education. Educational attainment alone fails to capture all aspects of knowledge, talent and skills that are critical for regions to manage the current industrial transition to an ever more intensive knowledge economy. Albeit higher levels of education are typically associated with stronger cognitive abilities. Areas with a higher share of jobs relying on routine tasks are likely to experience more disruption, whereas places where more jobs require tacit skills will face lower levels of risk. Tacit skills are based on experience and intuition instead of formal rules. Thus, they are more difficult to replicate through mechanical processes or standard algorithms. These jobs are in occupations such as engineering and sciences, but also those with a large component of social intelligence and creativity.

The skills that are becoming increasingly useful in the coming years are complementing formal education and training. Building on expert judgements, Frey and Osborne (2017[58]) estimate the likelihood that occupations can be automated, and the associated tasks and skills used in the occupations. Those skills that arise in the estimate with a lower risk of being automated are:

- Skills linked to perception and manipulation, especially if they require being involved in unstructured processes.
- Skills that require creativity, such as artistic activities or coming up with original ideas.
- Skills that rely on social intelligence, such as being persuasive, negotiating aspects of a project or caring for others.

All jobs have tasks with a different likelihood of being automated, not just those that "low-skilled" workers perform. This means that policies should stimulate skill upgrading across all types of jobs towards those that are less automatable, such as e.g. programming, presenting, influencing or training others. Employers already invest in training to upgrade the skills of their employees towards more relevant (or new) tasks. However, training is typically funnelled towards those workers that are already in high-skill categories, therefore policies may be required to address the re-skilling of lower-skilled workers.

Interpersonal and interregional inequality is likely to continue to rise through the fourth industrial revolution. As technological improvements allow substitute routine cognitive and manual skills, the wages of workers that rely on these skills will fall. This will affect workers in manufacturing but also services. This distinguishes the current transition from past transitions where the decline in manufacturing jobs was compensated by job creation in service sectors.

Regional networks and social capital

The element that binds the actors and assets within regional innovation systems are the regional "institutions". These institutions include formal and informal links, networks, local leadership but also cultural norms and the local image or identity. The presence and strengths of these institutions can be considered a form of "social" capital (Audretsch, 2015[109]), highlighting the productive nature of institutions. There is a wide consensus that social capital is important for fostering innovation but there is less agreement as to the importance of different aspects of social capital and even what aspects should be included altogether. The first volume of the *Handbook of Economic Growth*, published in 2005, which summarises the state of knowledge on growth theory, included a chapter on social capital as the 26th out of 28 chapters (Durlauf and Fafchamps, 2005[110]). The second volume published in 2014 included "culture", "trust" and "family ties" as topics in Chapters 1, 2 and 4.[12]

Social capital breaks silos between the main ingredients of well-functioning regional innovation systems. The key ingredients regions need for managing the third and fourth industrial transitions, such as knowledge, skilled labour and knowledge-intensive specialised suppliers, do not act in isolation. Regions may need social capital as co-ordinating social glue that enables finding synergies and generating new ideas through favouring a culture of networks and (productive) interactions (Audretsch, 2018[9]). Repeated social interactions raise social capital, as they reduce opportunism and increase the chances to escape from co-ordination failures (Moesen and Van Puyenbroeck, 2000[111]). A variety of regional institutions provide technical, financial and networking services enabling social interactions that contribute to the dynamism of regional innovation ecosystems. Examples of such institutions include universities, trade associations and local business organisations, as well as specialised consulting, market research, public relations and venture capital firms.

Social capital lowers transaction costs by increasing the quantity and quality of information available to local agents or by reducing the need for such information in the event agents greatly trust each other (Knack and Keefer, 1997[112]). Places with higher social capital do not need to rely on formal institutions, complete contracts and legal dispute resolution as much as in places where trust is less present (Tura and Harmaakorpi, 2005[113]). The resulting high trust in regions with high social capital favours the creation and diffusion of knowledge, which is critical for innovation and increases the feeling of mutual identification among agents, increasing the willingness to collaborate (Dincer and Uslaner, 2009[114]; Hauser, Tappeiner and Walde, 2007[115]).

The economic literature provides several examples of why social capital is important for economic growth due to its relevance for innovation activities. Higher levels of social capital increase the propensity of venture capitalists to finance risky projects because it lowers monitoring costs over the firms they decide to finance and decreases the probability of cheating by inventors, who are more concerned about their reputation when social capital is present. Social capital has an impact on patenting activities, which in turn explains 15% of GDP per capita growth in European regions between 1990 and 2002 (Akçomak and ter Weel, 2009[116]). Social capital can, however, also hinder innovative activity and the development of new economic sectors, in particular when it reinforces reliance on existing sectors (de Vaan, Frenken and Boschma, 2019[117]).

Social capital is often highlighted as the key factor that led to the innovation-driven rise of Silicon Valley, the tech-hub of the Bay Area around San Francisco in the United States. The seminal work of Saxenien (1994[118]) compares the development of Silicon Valley with the greater Boston area. Her analysis suggests that the regional innovative advantage of Silicon Valley stemmed from social capital. She found that while Silicon Valley was characterised by rich and vibrant networks and linkages, by contrast, people in the Boston region tended to work in a disconnected, autonomous manner with few linkages and interactions.

Two decades after the publication of her analysis, the upward trajectory of the Bay Area has barely changed. Greater Los Angeles (that had a similar starting point to the Bay Area in the 1970s), conversely has steadily fallen behind other US metropolitan areas. Networks, in particular among leaders within the private sector, remain a key distinguishing feature of the Bay Area. Through board memberships and, in particular, the linking role of business leadership organisations (such as the San Francisco Chamber of Commerce or the Bay Area Council), the network of private sector leaders is significantly denser in the Bay Area than in Los Angeles (Storper, 2018[119]). This is evident in other parts of the economy as well: 55% of inventors that filed a patent in biotechnology in Silicon Valley were part of a densely connected network of co-patenting inventors, while the same core group accounts only for 2% of inventors in Greater Los Angeles (Casper, 2009[120]).[13]

Social capital alone does not suffice to create innovative momentum but it can distinguish places that successfully transition from those that remain trapped in their current structures. The Bay Area, Greater Boston and Greater Los Angeles all had strong economic assets at the outset. Leading industries were concentrated in all three metropolitan regions, capital investment was high and the knowledge and skills of the local workforce strong. The networks within San Francisco, as well as the mindset of local leaders, supported the alignment of these assets towards new sectors. From the 1980s onwards, the public discourse in the Bay Area focused on the "new economy", while Los Angeles focused on the loss of manufacturing, civil unrest and the development of traditional infrastructure (Storper et al., 2015[121]).

Strategies to adapt to disruptions and transition

Innovation systems need to become more resilient and more adaptive in the face of disruptive technologies. A core dilemma is that disruptive innovations as well as innovation policy itself will create stronger gains in some places than in others and might even leave some places to fall behind. The solution to this dilemma is not to avoid innovation or to try to avoid disruption but rather to focus on preparing regions to be in the best possible position to seize new opportunities. Only a small number of regions might be able to be the "first mover" in a new sector or technology field but the diffusion of new knowledge and adaption of innovation is possible for all regions. A rise in inequality is endogenous to the diffusion process and social rather than innovation policy might be better suited to address it.

No single policy changes the economic makeup of a region. Whether regional policymakers aim to broaden or upgrade existing sectors or branch into new (related or unrelated) varieties, a combination of different efforts is required. In some cases, there are successful examples that regions can draw from but in many instances, there is no blueprint that can be adapted. Even past successes might not provide adequate guidance. The changing industrial and competitive landscape that characterises industrial transitions means that framework conditions are constantly changing.

How can a region prepare its economy for an industrial transition? A broad-based approach to innovation policy builds on some form of effective leadership in the region, engages all actors in the innovation system and actively seeks to harness knowledge from outside the region. Regional leadership helps to set a common agenda. It has the capacity to help develop a local mindset that helps discover new domains that secure existing and future competitiveness (Grillitsch and Sotarauta, 2018[122]). This requires an entrepreneurial attitude in the region (Grillitsch and Asheim, 2018[123]). This attitude is not just important for development in the private sector but "institutional entrepreneurship" within the public sector and at universities can be catalysts as well. The local assets in a region might not suffice to support the transition of a regional economy. Drawing from interregional networks, through links established by the public or the private sector, is an important source of stimulus for new development.

Looking back across the different industrial revolutions and the accompanying transitions, several elements emerge as drivers of success and failure of regions' ability to deal with change (Audretsch, 2015[109]). They are closely linked with the regional innovation system (see Chapter 2) as they build on local actors and resource endowments, the networks that connect them and the institutions and policies that shape their behaviour. These characteristics can be grouped into the four categories listed below.

Building on regional endowments

Leader vs. follower

First adopters often have an advantage over firms and regions that follow suit. The "first-mover advantage" is an integral part of the lifecycle of a product or even of industrial revolutions (see above). As markets develop, the early entrants can gain market shares and establish a dominant position that is only gradually challenged by new incumbents as the underlying technologies and products mature. In the regional context, this applies as well. Employment in knowledge-intensive services, such as ICT, is highly concentrated in one or two regions within a country (Daniele, Honiden and Lembcke, 2019[124]).

New disruptive technology is by definition a challenge for incumbents and thereby provide a window of opportunity for new entrants. To enter these windows of opportunity, latecomers need a reasonable productive capacity, human resources and locational advantage. Along the life cycle of a technology, windows of opportunity emerge as the industry undergoes changes in knowledge and technology, changes in demand, and changes in institutions and public policy (Lee and Malerba, 2017[125]). Frontier regions are well placed to benefit from the next wave of technological development but in the past some frontier regions were able unable to reinvent themselves, turning collections of resources into "communities of inertia".

To go through an open window of opportunity, regions behind the frontier need to develop their own distinguishing profile, providing that they have sufficient "absorptive capacity" (Foray, 2015[126]). Absorptive capacity is a broad concept and includes a workforce that can (easily) adapt to work in new sectors, entrepreneurs that can exploit new opportunities, policymakers that set the right framework conditions and provide support where needed and academic institutions that are willing to and can engage with the business sector.

The reflex in regions is often to "attract talent". Advanced regions can leverage their position as innovation leaders. Their existing knowledge base, the presence of leading firms and other advantages such as the availability of risk finance make them a natural point of attraction. Leading regions therefore often manage to sustain their advantages for long periods of time (OECD, 2018[16]). Attracting firms, innovative entrepreneurs or a skilled workforce can complement existing assets of a region but developing a whole ecosystem takes time and requires significant local efforts. Training and retaining should complement the efforts to attract outside support.

"Follower" regions have the advantage of learning from mistakes and successes in first-mover regions. Regions can thereby reduce the transition cost associated with disruptive innovations and maximise the benefits. A second advantage is that innovations and their supporting technologies have time to mature, capacity to produce or use the technologies can spread and firms and workers can learn from examples in other areas (OECD, 2019[81]). This means that the cost of production and adoption are lower. Regions that are competing on cost of production (as opposed to productivity and innovation) have therefore opportunities to enter new markets.

Industrial structure and embedded knowledge

Whether the region is a technological leader or a follower is only one aspect of their wider knowledge portfolio. The existing industrial structure, the knowledge embedded in the firms operating in a region and the strength and specialisation of local universities are essential assets when facing disruptive innovations.

Regional economies adapting innovations can – often most easily – branch into related technology fields (see the above discussion on regional diversification). This is also the case for disruptive technologies. When assessing regional capacity to manage disruptions, considering the region's current technological specialisation and firm capabilities is therefore one of the most important factors.

Disruptive technologies may open windows of opportunity for regions that have developed sufficient absorptive capacity. Regional branching is often into related varieties, so existing specialisations can largely determine the ability to take advantage of current developments in a new domain (Frenken, Van Oort and Verburg, 2007[34]). By upsetting the existing order and challenging incumbents, a sufficiently prepared and flexible region can also establish itself as a new leader. An important enabler for such a move can be the spread of "general-purpose technologies", i.e. those underlying technologies that enable disruptive innovations. Recent evidence for 26 European countries suggests that regions with some activity in general-purpose technologies are more likely to develop a broader industrial base and activity in more – unrelated – sectors (Montresor and Quatraro, 2017[127]).[14] The study relies on patent activity in general-purpose technologies, which has the drawback that patenting tends to be very much concentrated in leading regions. Whether and how regions with a less technologically advanced knowledge base can benefit remains an open question.

The position of a region and its firms within supply and (global) value chains affects the risks and opportunities from disruptive innovation. Some technologies are more upstream or downstream than others in the innovation network. This implies a structure of interdependence between regions (Acemoglu, Akcigit and Kerr, 2016[75]). Regions focusing on downstream technologies are potentially able to benefit from externalities from innovation in other domains or region, but this also makes them dependent and thus vulnerable in case the upstream knowledge generation decreases. Examples include health, where applications of new therapies rely on continuous innovation in pharmaceuticals, and renewable energy, where progress in renewable energy has been partly driven by semiconductors and digital technologies. Technologies can be more directed towards specific parts of the value-chain, from conception to production, marketing and distribution. Regional positioning in the value chains matter because upstream activities, such as R&D, have more value-added than middle stream activities, such as manufacturing marketing (OECD, 2018[128]).

Legacy infrastructure

The regional impact of a disruptive technology depends on the existing infrastructures and ability of a place to adapt them. Transport infrastructure, the telecommunication and broadband network but also infrastructures such as science and technology parks determine the adaptability of a region. Market failures are likely to be more important in infrastructure building than in other domains, as decisions taken years or decades ago affect current capacities. As a result, public policies for infrastructure remain not only a major priority for overall development but also a key instrument for ensuring access to development opportunities across regions and thereby territorial inclusiveness.

Each industrial revolution has been associated with key technologies (see above) as well as the supporting infrastructure network. Investment in railways, electricity networks and today's digital infrastructure are necessary for regions to be part of the industrial revolution. The more infrastructure-dependent technologies are, the stronger will be their local effect (Perez, 2003[129]). An example of relevant infrastructure for disruptive technologies is digital infrastructure. The "digital divide" in terms of access to broadband infrastructure remains important (in particular in terms of speed of Internet access) but disruptive technologies in energy and transport may appear even more infrastructure-intensive.

Geography

Agglomeration tends to be driven by human factors rather than physical geography but some aspects of physical geography may matter, especially in relation to global trends. Climate change will affect regions differently, both directly through disasters and sea-level rise and through migration from adjacent areas. Accessibility to input materials remains an important factor for technological breakthroughs or incremental technological change. However, physical materials are most often sourced from the international market, not having to be sourced regionally.

Proximity to other regions

Distance matter in innovation, both for the frontier and innovation diffusion. Innovation processes have no borders. Recent empirical work emphasises that regions are not isolated, being important to consider spatial structure to understand the impact of policies (Autant-Bernard, Fadairo and Massard, 2013[130]). Regions should consider their strength and weaknesses in link with that of their neighbours, considering system-wide implications, and this, of course, requires significant efforts of policy co-ordination at the national and supranational levels (OECD, 2018[128]). Interregional links are particularly important when physical infrastructure plays an important role, as a region can benefit from connecting to a neighbour's network. Physical proximity also matters for migration, including (in- or out-) migration of skilled workers (Miguélez and Moreno, 2015[131]) as well as for patenting activity – even within Silicon Valley (Kerr and Kominers, 2015[132]). Despite the increased possibility of accessing knowledge remotely, distance thus remains an important regional characteristic to consider (Paunov et al., 2019[94]).

City systems and agglomeration economies

"Cities deliver the random exchanges of insight that generate new ideas for solving the most intransigent problems" (Glaeser, 2011, p. 51[133]). This does not mean that only the largest megacities can produce innovation, but density and "agglomeration economies" favour both productivity and innovation (OECD, 2015[83]). Large cities create more opportunities for interactions but they also attract a larger share of more qualified or "skilled" people.[15] The higher share of highly skilled workers makes cities more resilient to disruptions. They tend to have more managerial and technical professionals, reducing the risk of job losses from automation (Frank et al., 2018[27]). They also offer larger and more diverse labour markets that make it easier for workers to transition to new opportunities.

Cities can create benefits beyond their borders. This is particularly evident for cities that are "well-functioning" (OECD, 2018[128]), i.e. well integrated with their surrounding commuting zone. Achieving this goes beyond purely urban planning and needs a regional view that acknowledges agglomeration costs and considers well-being beyond purely economic indicators. Beyond the urban-rural dichotomy, geographers have shown that it not possible to understand city growth and the location of activities without reference to systems of cities. Urban economic and innovation policy should strive to consider cities within their wider sphere of influence, as (physical or otherwise) proximity to other cities influences innovation diffusion and competition.[16]

Some technologies might have a more Jacobian (across sectors) or more Marshallian (within sectors) potential, and this determines what region should target them or be affected. Some technological ecosystems with very wide applicability, such as all technologies related digital innovation, could thrive in diverse cities thanks to the good match between the diversity of the city and the large potential applications of the technology. In contrast, more specific technological domains are likely to benefit more Marshallian externalities, such as health technologies thriving in regions with large medical universities producing a pool of highly specialised workers. For instance, current national strategies for AI discuss both developments of the technology in terms of fundamental capabilities and in terms of "recombining" AI with various applications domains.

Developing local and regional leadership

The role of regional leaders is to develop a shared vision providing local actors with a sense of direction, in order to enable regional industrial rejuvenation. Regional leadership consists of an orchestration in "quadruple helix" processes that gathers leaders from local industries, academia, public authorities and non-profit organisations. Regional leadership played a key role in the success of Silicon Valley (see above). Interactions between local leaders from different communities fostered a new vision for the region centred on a "technological approach to better modern living". Important members of the San Francisco downtown finance and corporate elite were on the boards of directors of the major environmental organisations, resulting in the creation of networks interacting with the technology community (Storper, 2018[119]).

Regional leadership in Silicon Valley helped bring different groups together under a shared vision. Leaders from traditional engineering networks from the defence-aerospace-communications sector, intertwined with leaders from "hippie" groups proposing alternative technology futures for cities and modern life, and started working on common goals. The elite leadership groups in the Bay Area endorsed early on the new economic vision for the world and the Bay Area's role in it, engaging in "making it happen". A key element of success was not only the existence of leaders but also the depth of how interconnected their networks became (Storper et al., 2015[121]). A prominent example is the creation of an organised site of contact between local networks established in 1969, by Xerox, founding the Palo Alto Research Centre (PARC). Three networks came together there embracing a common vision: the engineering-based corporate world, with its focus on military procurement; the conventional, academic engineering research community; and the Bay Area alternative technology and environmental circle.

A shared vision for a region might require democratising the process of policymaking, including the design of regional innovation policies and defining strategic technological paths. This can involve, for example, engaging the "quadruple helix" by identifying and gathering leaders from different regional stakeholders, such as local industries, academia, public authorities and non-profit organisations, and pursuing participative governance processes defining regional innovation strategies. Regional innovation policies are likely to fail if local agents do not support the broad strategic vision for the region's economic rejuvenation. In addition to a well-defined vision, stimulating interactions across different local leaders can contribute to increasing innovation ecosystems' dynamism, with for example the promotion of internal events (for local networking) or external events (representing the region, e.g. at trade fairs), and incentives for collaborative R&D.

Regional leadership contributes to innovation by formulating and implementing both a vision and strategy for innovation, as well as in communicating that strategy and innovation to local agents. In addition, leadership can help transform the identity of a region to the rest of the world as well as the region's own self-image, which is important in order to attract and retain talent and foster human interactions among local agents. Regional leadership can come from the public sector, but examples of leadership from the private sector or civil society, as well as shared leadership, exist (see Box 3.7).

Box 3.7. Leadership in regional innovation policy

North Carolina, United States

Leadership can come from outside the public sector, for example through philanthropic contributions. Wealthy and established citizens originally capitalised North Carolina's Research Triangle Park largely through philanthropic contributions. During the second industrial revolution, North Carolina ranked as the poorest state in the United States. However, during the third industrial transition to the computer era, the creation of the Research Triangle helped to turn the region into one of the most innovative and prosperous regions in the world.

A number of anonymous North Carolinians bought the land for the park's site, which was then transferred to the non-profit Research Triangle Foundation (Link, 1995[44]). These funds also enabled the establishment of the Research Triangle Institute, which performed contract research for industry and government sponsors. The establishment of foundations can reduce the cycle time for decisions and their execution, which is a key factor in regions' competitiveness. Foundations can be more agile as they are not subject to the bureaucracy of state universities and thereby enable researchers to interact with firms competing in a rapidly evolving technological landscape.

Basque Community, Spain

Regional leadership played a key role in facilitating a positive shift from the second to the third industrial transition in the Basque Community in Spain. During the second industrial era, the region developed a policy strategy around shipbuilding. However, by the 1980s, during the third industrial transition, the Basque Community region lost its competitive advantage in shipbuilding, economic growth stagnated and unemployment rose abruptly (OECD, 2011[134]).

The strategy to help the region manage the industrial transition consisted in shifting the identity and image of the region from manufacturing, based on combining physical capital and low skills, to a region featuring culture, hospitality and innovation. The strategy included procuring the Guggenheim at Bilbao, requiring a substantial investment. Regional leadership was important to overcome the inertia and resistance against the new policy approach (OECD, 2011[134]).

Tampere, Finland

From the 1990s, Tampere moved towards a university-driven knowledge economy, becoming a Nokia-led global ICT hub in the early 2010s. With the closure of Nokia's research facility, Tampere needed to act quickly to retain the highly qualified workforce in the region and to maintain its image as a dynamic and innovate region. Local and regional politicians worked with local firms to develop ad hoc actions in response to the crisis. The region also realised that it was necessary to transition from its regional cluster specialisation policy (1994-2013) towards an open innovation platform policy, which started in 2009 (OECD, 2018[16]).

Tampere was able to reshape its economic structure based on the dominance of a large company, into an entrepreneurial ecosystem of innovative technological start-ups, combining the regions' knowledge about building machines, with IoT features. Nokia's former employees launched some of these start-ups. Tampere uses its regional branding as a dynamic, innovative and pleasant region to live, in order to attract and retain talent and thereby attract companies to set up R&D labs.

Source: Link, A. (1995[44]), *A Generosity of Spirit: The Early History of the Research Triangle Park*, Research Triangle Foundation of North Carolina; OECD (2011[134]), *OECD Reviews of Regional Innovation: Basque Country, Spain 2011*, https://dx.doi.org/10.1787/9789264097377-en; OECD (2018[16]), *Productivity and Jobs in a Globalised World: (How) Can All Regions Benefit?*, https://dx.doi.org/10.1787/9789264293137-en.

Institutional entrepreneurship

Institutions are seen as a set of formal and informal rules, regulations and constraints on the one hand, and organisations in the form of economic, political, social and educational bodies on the other. Institutional entrepreneurship consists of the adaptation of formal or informal rules and the creation of new institutions and public programmes that are conducive to entrepreneurship and innovation (Rodríguez-Pose and Storper, 2009[135]). Institutional entrepreneurs are individuals, groups or organisations initiating change processes and contributing to the creation of new institutions or transformation of existing ones (Battilana, Leca and Boxenbaum, 2009[136]).

Institutions can foster a regional culture that is prone to entrepreneurial activity. A starting point for the creation of an entrepreneurship culture can be to install an entrepreneurship-friendly institutional framework. For example, Darnihamedani et al. (2018[137]) show that well-designed tax policies can increase the level of entrepreneurship. Measures that can indirectly spur the public opinion about entrepreneurship include awareness campaigns (e.g. portraying of successful entrepreneurs in the media) that may trigger a positive perception of entrepreneurial behaviour (Fritsch and Wyrwich, 2018[138]).

The role of institutions goes beyond setting formal and informal rules or acting as intermediaries; institutions can also make market-related entrepreneurship possible. Public procurement through the Defense Advanced Research Projects Agency (DARPA) in the United States resulted in many of the inventions that underpinned the third industrial revolution. Research funded by the long-standing agency resulted, among others, in the development of the Internet (Mazzucato, 2013[139]). DARPA is the most prominent example of active institutional entrepreneurship but other agencies, e.g. the Korean Centres for Creative Economy and Innovation follow a targeted approach in intervening on specific technological fields (Box 3.1).

Developing an attitude of institutional entrepreneurship in a region takes time. Agencies that support an entrepreneurial approach can be a starting point. An example of the creation of new agencies that aim to foster innovation in a region are regional innovation intermediaries such as the Centre for Economic Growth in the capital region of the state of New York, or the Centre for Technological Innovation and Advanced in Andalusia, Spain (Box 3.8).

Box 3.8. Leveraging innovation intermediaries

Center for Economic Growth, New York (United States)

The Center for Economic Growth (CEG) was created to address the fragmentation of local authorities in New York's capital region. The Albany-Colonie Chamber of Commerce created the CEG to spearhead the development and implementation of coherent strategies for regional development. New York's capital region faced challenges with balkanised governmental jurisdictions and institutions that were viewed by the business community as obstacles to regional economic growth.

The CEG functioned as an advocacy group as well as a think tank organisation that committed resources to survey and understand successful innovation-based development initiatives in other parts of the United States and around the world. It promoted the use of the term "Tech Valley" to rebrand the capital region and to market it to high tech companies. Subsequently, CEG played a major role in breaking down institutional barriers to co-operation and forging co-ordinated regional initiatives able to attract state support.

Leveraging the entrepreneurial discovery process, Andalusia (Spain)

Andalusia has bundled its investment promotion, risk capital funding and innovation programmes in its Innovation and Development Agency (IDEA). IDEA focuses on Andalusian business support, managing projects and programmes of the Ministry of Employment, Enterprise and Commerce, as well as on promoting the establishment of industrial and technological infrastructures related to Andalusian strategic clusters. Leveraging the "Entrepreneurial Discovery Process" that was part of the development of the Andalusian Regional Innovation and Smart Specialisation Strategy, the region developed a plan to extend its existing strength in the aerospace industry.

The assessment found that a facility of researchers who can co-develop prototypes with SMEs was missing. With the Centre for Technological Innovation and Advanced Aeronautical and Naval Manufacturing (CFA), the region provides a place and infrastructure (80% of the investment will be in machinery) where collaboration can take place. The project aims to support cross-sectoral space, naval and aerospace technologies. Technical specifications were developed in collaboration with the business sector and with the universities. The initiative also includes the development of dual degree programmes at the university that aim to train students to work in the facility.

The centre is an example of a multi-stakeholder collaboration between the Junta de Andalucía, local public agencies such as IDEA and the main actors of the private sectors including Airbus, Navantia, the University of Cádiz, the naval maritime cluster of Cádiz and the Andalusian aerospace cluster. The CFA contributes to the identification of opportunities for collaborations both globally and locally, develops foresight capacity and anticipatory action to potential external shocks, connects regional capacities and upgrades them through multi-stakeholder collaborations on new joint projects.

Source: Wessner, C. and T. Howell (2018[10]), "Smart specialisation in U.S. regional policy: Successes, setbacks and best practices", Background Report for an OECD/EC Workshop Series on Broadening Innovation Policy: New Insights for Regions and Cities, OECD, 15 October 2018, Paris; OECD (2010[140]), *Higher Education in Regional and City Development: Andalusia, Spain 2010*, https://dx.doi.org/10.1787/9789264088993-en; EC (n.d.[141]), *Innovation and Development Agency of Andalusia (IDEA Agency)*, https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/organisation/innovation-and-development-agency-andalusia-idea-agency (accessed 10 July 2019); Invest in Spain (n.d.[142]), "The Andalusian Regional Government equips the Innovation Centre of Cádiz", http://www.investinspain.org/invest/en/press-room/Business/news/NEW2017737967_EN_US.html (accessed 10 July 2019).

Experimentation, learning and openness

A large degree of uncertainty surrounds the opportunities that innovation will bring in the coming years and how they will affect different regions and populations. To ensure that regions remain competitive through fulfilling their development potential, policy needs to tackle this uncertainty. This means building on the existing evidence base and extending it. Many aspects of the innovation process are not systematically measured. Links between actors, institutions and policy that underpins innovation systems are hard to capture. Progress needs to be made in using and linking different microdata sources that allow to systematically assess the importance of different links and the ability of policy to affect them. Another aspect is the role of investment in intangible assets and the capacity of firms to collateralise intangibles (OECD, 2013[143]). Especially at times where "data is the new gold", the question of how access to data can be facilitated, governed and aligned with privacy concerns is critical.[17]

To address uncertainty, policy experimentation and learning are key. Experimentation for large-scale programmes is rare. One more common approach to policy experimentation is to assemble a portfolio of promising projects and programmes that are then implemented at a small scale as pilots or trials. Key is that they can be implemented, financed and scaled up once they show promise through the monitoring phase. The monitoring phase should not be passive but policymakers should use the phase to revise or even eliminate poorly performing initiatives (Dutz et al., 2014[19]). The objective of monitoring and evaluation should, however, not be on deciding what to cut but on improving the programmes and drawing lessons from the process that help in policy (re)design (OECD, 2017[144]). Whether policies or programmes are rolled out widely or in smaller trial phases, a critical element is how policymakers learn from success and failure (see also Chapter 5). Learning through peer exchanges with other regions can be an important tool in this respect.

Disruptive innovations often come through recombination of existing technologies and much of the expected progress in the coming years is at the intersection of a different academic field. An interdisciplinary approach both in the private and public sectors is therefore critical. An open question is whether traditional R&D models can facilitate this approach or whether the traditional "closed" innovation system approach needs to become an "open" innovation model (Chesbrough, 2003[145]). In the traditional development model, the R&D process was fully integrated within the boundaries of a firm and often physically separated by highly protected research facilities. This closed system can help firms capitalise on inventions and innovations as learning by competitors is slowed. But a closed system misses opportunities to gain knowledge from external sources and co-creation of innovation, e.g. along the supply chain or with academia. This is particularly important when the knowledge base is tacit, i.e. hard to codify. In this case, communities of practice will develop and the industry may have a strong local dimension (Amin and Cohendet, 2004[146]).

Universities as a catalyst of regional innovation and entrepreneurship

Universities will play a key role in the fourth industrial revolution, given their importance in addressing the main factors and resources associated with the knowledge economy, such as human capital, creativity and other skills. Universities and other public research organisations have a strong local impact on innovation outputs. Half of all inventors who filed patents in the 36 countries in the OECD database of higher education and public research institutions live within 30 kilometres of a university or public research institution. In part, this link is driven by local characteristics that support both academic and patenting activity (e.g. a strong industrial economy). Regression results that account for these confounding factors confirm that universities and public research institutions have an additional, local effect on patenting activity (OECD, 2019[147]). The creation of the College of Nano Scale Science & Engineering (CNSE) is an example of a new research institution with a strong regional impact (Box 3.9).

Box 3.9. The College of Nano Scale Science & Engineering, Unites States

The Albany-Malta corridor along Route 9, also termed Nano-tech Valley in New York State (United States) provides a successful example of policies leveraging the role of universities for regional technological rejuvenation. The state invested in industry-relevant R&D in local research universities, which helped these institutions secure recognition by the industry's Semiconductor Research Corporation. New York State universities were open to engagements with industry, able to carry out applied research and train students to work with new technologies.

The region benefitted from a new research institution specifically designed to address the opportunity of nanotechnologies, with a focus on the needs of the semiconductor industry: the College of Nano Scale Science & Engineering (CNSE). The CNSE became a driver of regional employment and catalyst of an ecosystem, attracting major players in the field interested in maintaining and exploiting the college's facilities.

The CNSE created numerous research consortia with semiconductor device, equipment and materials companies, with arrangements that minimised the cost and risk associated with introducing new tools and processes. Sharing the costs of research, participating firms could test equipment and techniques developing and refining expertise and identifying and ironing out "bugs" in new-generation tools and processes before investing in their own manufacturing facilities. The college shared research facilities in which companies and CNSE staff could collaborate as well as proprietary space rented by individual companies where the firms can take expertise and technology generated in the joint activity for refinement into their own proprietary products and industrial processes.

Source: Wessner, C. and T. Howell (2018[10]), "Smart specialisation in U.S. regional policy: Successes, setbacks and best practices", Background Report for an OECD/EC Workshop Series on Broadening Innovation Policy: New Insights for Regions and Cities, OECD, 15 October 2018, Paris.

The mechanism behind the well-established fact that firms with closer science links perform better is still much of a black box. The role that universities play for regional innovation differs depending on the characteristics of the university and of the region. Spending on universities that grant advanced degrees (four-year degrees in US colleges) has a stronger impact on patenting in regions that are already close to the technological frontier (Aghion et al., 2009[148]). The type of expenditure, competition among universities and the autonomy of the university also affect patenting and academic publication activity, with some evidence that institutions learn and become more productive through repeated participation in funding competitions (Aghion et al., 2010[149]). Moreover, Bloom et al. (2017[150]) find that firms located close to universities are more likely to adopt structured management practices that are associated with better firm performance.

Universities are important catalysts for entrepreneurial ecosystems. University research and other public research organisations contribute with applied research that can lead to new innovative products and services, that can be commercialised for example through academic spin-offs and collaborations with established firms. Universities also contribute to attract and educate students with entrepreneurial skills through their education function. Including entrepreneurship courses as part of a formal university curriculum and hosting incubators are examples of approaches to strengthen links with local entrepreneurs (Box 3.10).

Box 3.10. The role of universities in Chicago's entrepreneurial ecosystem

During the early 2000s, the city of Chicago in the United States was not a major player in the start-up ecosystem but in about 10 years the city became one of the most important cities in entrepreneurial technology. Chicago's entrepreneurial ecosystem started to emerge after numerous public initiatives started using regional universities to foster entrepreneurship. The state of Illinois managed to shift away from a focus on large and established firms.

Public initiatives to change this scenario included, for example, increased budgets for scientific research that can lead to university spin-offs, the creation of funds to invest in student entrepreneurship and the creation of university start-up accelerators. The International Institute for Nanotechnology was created at Northwestern University with the objective of launching start-ups to commercialise nanotechnologies developed at Northwestern University.

The University of Illinois created curricula designed to foster entrepreneurship, including business plan competitions, funding for proof of concept and a residential dormitory for students from different fields who are interested in becoming entrepreneurs. The University of Chicago's New Venture Challenge programme has been recognised as the number one university accelerator in the United States, and its Innovation Fund invests in local start-ups.

Source: Wessner, C. and T. Howell (2018[10]), "Smart specialisation in U.S. regional policy: Successes, setbacks and best practices", Background Report for an OECD/EC Workshop Series on Broadening Innovation Policy: New Insights for Regions and Cities, OECD, 15 October 2018, Paris.

Interregional collaboration for economic diversification

Moving into new sectors often requires an external stimulus. Regional economic rejuvenation centred on the pursuit of innovation requires both intra- and inter-regional networks for innovation and the development of new specialisations. The most innovative regions generally engage in a large number of collaborations. For example, Baden-Württemberg in Germany has an open and international network focused on Northern Europe and North America. In the United States, California is a leading hub in the global network and collaborates frequently with firms from emerging countries such as China and India.

Interregional links do not need to be international. Public policy can contribute to foster knowledge diffusion by strengthening rural-urban linkages. Leveraging local and proximate urban centres is a key asset for rural regions. Productivity in rural regions close to cities has grown faster than in remote rural areas. Since 2009, rural regions close to cities have been able to narrow the productivity gap to predominantly urban regions (OECD, 2018[151]). Diffusion of knowledge and shared innovation activity is facilitated by proximity, but rural and urban regions are connected in various ways that also shape the effectiveness of diffusion channels, e.g. through the delivery of public services and multi-level governance interactions (OECD, 2016[25]).

Rural-urban linkages may be difficult to achieve through market processes due to barriers such as weak regional ties, differences in regional regulation, institutional fragmentation or differences in language or business cultures. Policies fostering the development of regional collaborations have a pivotal role in harnessing the development of interregional value chains. They also often require initial policy incentives to get actors at the table since they face an inherent asymmetry in power relations between big and small regions. Many OECD countries encourage rural-urban partnerships by mandating co-submission as a requirement to access programme funding. France's reciprocity contracts offer one example of an approach that promotes intermunicipal collaboration (Box 3.11).

Box 3.11. Reciprocity contracts for stronger regional linkages, France

Well-aware of the complementarity potential of its different urban and rural territories, France has developed a new experimental tool to promote intermunicipal collaboration: "city-countryside contracts of reciprocity" (*Contrats de réciprocité ville-campagne*). These agreements are adaptable to different territorial realities; their jurisdictions are not pre-defined which allows them to cover different areas depending on the issue at hand. The process is primarily led at the intermunicipal level, with the state, regions and *départements* being asked to support local initiatives.

France's "contracts of reciprocity" acknowledge the diversity of rural areas and seek to strengthen and valorise urban-rural linkages. This is driven by an understanding that urban-rural interactions should address not just proximity issues (e.g. commuting patterns) but also consider reciprocal exchanges in order to build meaningful partnerships. Potential areas for co-operation include:

- Environmental and energy transition (e.g. waste management, food security, the preservation of agricultural land and natural areas, and bioenergy development).
- Economic development (e.g. the joint promotion of the territory and the development of joint territorial strategies, land use policies, support for businesses and the development of teleworking to help maintain remote towns centres).
- The quality of services (e.g. promoting tourist sites, access to sports facilities, leisure, heritage and access to health services).
- Administrative organisation (e.g. mobilisation of staff with specific skills to support key projects or needs).

Source: OECD (2016[25]),, *OECD Regional Outlook 2016: Productive Regions for Inclusive Societies*, https://dx.doi.org/10.1787/9789264260245-en; based on CGET (2015[152]), Note d'information sur les contrats de réciprocité ville-campagne; Ministère de la Cohésion des territoires et des Relations avec les collectivités territoriales (n.d.[153]), *Point sur l'expérimentation de contrats de réciprocité*, www.logement.gouv.fr/experimenter-les-premiers-contrats-de-reciprocite-ville-campagne-crvc (accessed 22 June 2016); French Government (2016[154]), *Compte rendu du Conseil des ministres du 6 juillet 2016*, www.gouvernement.fr/conseil-des-ministres/2016-07-06/le-pacte-etat-metropole (accessed 18 July 2016).

International affairs are traditionally in the purview of national governments, but regional and local governments can and increasingly do play an important role in linking their economies with those in other countries. Just pushing development through measures that regional or national government can affect is often not enough, but requires external links. This helps regions to focus on their core competencies and leverage knowledge and capacity from other places. These efforts can come through policymakers in the region itself but can also be facilitated at higher levels of government. The European Vanguard Initiative is an example of a bottom-up effort to link regions with economic complementarities across Europe (Box 3.12).

Box 3.12. The Vanguard Initiative, European Union

The Vanguard Initiative for New Growth through Smart Specialisation is a platform of European regions that strive to be frontrunners in applying “smart specialisation” as a strategic principle in EU innovation and industrial policy, to promote new growth by bottom-up dynamics stemming from the regions. Vanguard is a voluntary commitment by regions that adhere to the 2013 Milan Declaration. It seeks to promote multi-level governance and interregional collaborations, and identifies synergies between policies and works to explore regional complementarities identified in smart specialisation strategies.

The key objectives of the policy initiative are to:

- Bring together regions where there is a political will to play an active role in transforming regional clusters into world-class clusters.
- Create favourable framework conditions for cross-regional private co-investment.
- Develop new instruments to support bottom-up entrepreneurship, co-creation and clusters.

Vanguard builds on the idea that all levels of government in Europe can contribute to foster innovation and demand-driven investment. Regions are the right place to address innovative ecosystems, making the links between Europe, industry and research centres, as well as citizens.

The underlying rationale is that regionally developed ecosystems, connected across Europe, can be the driver of new European value chains. This requires the development of a stronger multi-level governance model, combining policy levers at different levels to reach shared goals.

Source: OECD (n.d.[155]), OECD STIP Compass, OECD, Paris, https://stip.oecd.org/stip.html (accessed 21 August 2019); Vanguard (2016[156]), “Regions and future EU policies for growth and investment”, https://www.s3vanguardinitiative.eu/sites/default/files/contact/image/vi_position_paper_post2020_final_7nov2016.pdf.

The new industrial policy of the Italian region of Emilia Romagna introduced in 2015 stresses the importance of external links. The policy acknowledges that complementarities can not only be found within the region but across a wider network. It also builds on the idea that the search for economic complementarities should not be left to the private sector alone. Links outside the region are formalised through strategic partnerships with regions in Europe, the People’s Republic of China, South Africa and the United States (Box 3.13). Emilia Romagna also engages in international collaboration within Europe through bottom-up networks, such as the Vanguard and through European Commission (EC) initiatives (e.g. the region is engaged in different Interreg projects).[18]

Regional networking within Emilia Romagna has a dedicated agency as a facilitator. ASTER was created in the 1990s to favour interactions within the regional innovation system. Its main concern is the industrial application of research and the promotion and realisation of concrete projects in this respect. It was reorganised in 2001 as a consortium gathering all regional actors of the innovation system: universities, research centres, business associations and the regional government. In 2019, the role of the agency was further strengthened through the merger with the regional development agency (*ERVET*) into a combined agency ART-ER (*Attrattività Ricerca Territorio*). ASTER initially aimed to promote technological transfer within the region but its role has evolved to also support extra-regional links since it is involved in the management and realisation of Emilia Romagna’s projects that are part of the European Interreg programmes and those that contribute to the Vanguard Initiative (Labory and Bianchi, 2018[157]).

Box 3.13. Interregional collaborations in Emilia Romagna, Italy

The region of Emilia Romagna has pursued complementarities beyond regional borders, collaborating with other Italian regions and in foreign countries. The regional government has favoured the development of linkages with other regions encouraging the participation of regional businesses (and other institutions such as universities). An example of this approach is the development of the Big Data Technopole. The technopole is included in a national network of big data centres that the region contributed to creating.

The region has six key partner regions, with which it develops close relationships in all fields. Key partners include the European regions of Aquitaine (France), Hessen (Germany) and Wielkopolska (Poland), and the three extra-EU regions are California (United States), Gaudeng (South Africa) and Guangdong (People's Republic of China). Emilia Romagna is also a member of various interregional programmes, such as Adrion with regions bordering the Adriatic and Ionian seas, the Italy-Croatia programme or the Alps programme. These programmes finance R&D projects in fields of common interest (e.g. marine technologies for SMEs in the regions bordering the Adriatic Sea) so that interregional complementarities can be exploited.

The Agenzia per lo Sviluppo Tecnologico dell'Emilia Romagna (ASTER) agency is an innovation intermediary organisation that supports interregional networking activities. It was created in the 1990s to favour interactions within the regional innovation system and was re-organised in 2001 as a consortium gathering all the regional actors of the innovation system. Actors include universities, research centres, business associations and the regional government. The primary aim of ASTER is to favour technological transfer in Emilia Romagna and the promotion of extra-regional links, being involved in the management of projects within Emilia Romagna's interregional programmes.

Source: Labory, S. and P. Bianchi (2018[8]), "What policies, initiatives or programmes can support attracting, embedding and reshaping GVCs in regions?", Background Report for an OECD/EC Workshop Series on Broadening Innovation Policy: New Insights for Regions and Cities, OECD, 21 September 2018, Paris.

International collaborations are often easiest across a shared border. These cross-border collaborations can be a bridge that complements other global interactions. Innovating with a cross-border partner requires a degree of openness, which can be a first step towards internationalisation. Cross-border linkages are especially relevant for many SMEs that often lack the capacity for engaging in innovation and knowledge sourcing activities on a global scale. For example, commercial ties among SMEs across the border between Ireland and Northern Ireland (United Kingdom) were used as a stepping stone for wider engagement with GVCs (OECD (2013[158]); see also Chapter 4).

Political commitment is an important factor for kick-starting or securing long-term support for cross-border efforts. Generally, the local level has the strongest interest because it feels the costs and benefits most directly. For innovation policy, a region is typically a more appropriate scale than a locality to include the relevant range of firms, universities, workers and other innovation actors. Despite the potential gains, barriers in terms of sharing the benefits and risk associated with joint innovation efforts often limit effective collaboration (OECD, 2013[158]). InterTrade Ireland is one of the few examples of co-funded cross-border innovation initiatives that promote cross-border regional collaboration between Ireland and Northern Ireland (Box 3.14).

Box 3.14. InterTrade Ireland, Ireland and the United Kingdom

InterTrade Ireland (ITI) is a cross-border Trade and Business Development body that supports companies and researchers from Ireland and Northern Ireland to collaborate on Horizon 2020 (EU Science funding project). The key objective of the policy is to assist companies and researchers from Ireland and Northern Ireland to collaborate on Horizon 2020. It is a rare example internationally of a cross-border entity to promote trade and innovation that is co-funded by the respective governments.

During 2017, InterTrade Ireland has continued to expand its Horizon 2020 activities with a view to increasing joint North-South participation and a range of awareness-raising initiatives and supports for potential partners have been organised. Between January 2014 and June 2017, 52 partnerships received funding.

Source: Nauwelaers, C., K. Maguire and G. Ajmone Marsan (2013[159]), "The Case of Ireland-Northern Ireland (United Kingdom) – Regions and Innovation: Collaborating Across Borders", https://dx.doi.org/10.1787/5k3xv0llxhmr-en; country responses to the OECD Science, Technology and Industry Outlook 2016 policy questionnaire; EC/OECD (2016[160]), *International Science, Technology and Innovation Policy (STIP) Database*, https://www.innovationpolicyplatform.org/sti-policy-database.

Breaking silos through innovation centres and districts

Two popular modes of innovation support are linked to closed and open innovation systems. Regions and cities can leverage research centres in a targeted effort to promote innovation districts that have a broader mandate in linking actors. Under the research centres approach, a wide range of innovation-related policies are co-ordinated and consolidated under one administrative structure. The centre develops policies that support the adoption of disruptive technologies at the regional scale through continuing investments in regional innovation systems, such as specialised labour markets, firm networks and connecting fundamental research in universities and national labs to existing industry and firms. Under the innovation districts approach, cities or regions target the diffusion and absorption of enabling technologies at the regional scale. Cities or regions design and implement policies and services at a local level targeting start-up and scale-up activities, migration, workforce development and certification, and other innovation-related policies for example.

Research centres approach

Regional and national governments use research centres to centralise regional innovation policy under one administrative roof. Research centres serve as market intermediaries tasked with technology diffusion and development, and attempt to co-ordinate and align local actors and activities. Research centres increasingly bridge the gap between basic research financed and supported by public sector actors and the commercialisation of innovations facilitated by private-sector actors. The regional presence of research centres can follow a top-down (national to regional) approach where institutes of national importance are spread across different regions, or a bottom-up approach where centres answer to the needs of local agents supporting existing and evolving regional specialisations.

The National Network of Manufacturing Institutes (NNMI) is an example of a top-down policy effort in the United States using research centres to sustain regional innovation systems (Box 3.15). The network is composed of a total of 14 centres. The NNMI attempted to affect regional industrial specialisations through elaborated research, design and commercialisation centre model focused on targeted technologies rather than existing local industrial sectors (Clark, 2018[161]).

Box 3.15. National Network for Manufacturing Innovation Institutes (NNMI), United States

Beginning in 2010, the Obama Administration initiated the Advanced Manufacturing Partnership (AMP), which entailed rounds of private-sector and university-led policy development charged with diagnosing, analysing and acting to support industrial development and specifically address the gap between innovation and commercialisation in the United States economy. Co-ordinated by the President's Council of Science and Technology Advisers which spanned across departments such as Energy, Defence, Commerce and Transportation, the resulting policy prescriptions primarily addressed the economic crisis by initiating an architecture for a national innovation system that connected local and regional production systems to emerging and enabling technologies.

The Advanced Manufacturing Partnerships 1.0 (AMP 1.0) and 2.0 (AMP 2.0), which operated from 2011 to 2014, resulted in two policy strategy reports. Both reports recommended a NNMI. The NNMI initiative created large-scale research centres (individually manufacturing innovation institutes or MIIs) connected to industry, universities and the broader set of institutions constituting both regional and national innovation ecosystems defined by targeted technologies. This policy model explicitly acknowledged that national innovation investments diffuse more effectively when they are co-located with regional production capacities, as they are in the EU, Canada and Germany (Clark, 2014[162]). The original Advanced Manufacturing Partnership proposal for the NNMI suggested 50 or more MIIs, each focused on technology relevant to the future of advanced manufacturing in the United States. The new policy targeted federal investment in technologies rather than industries (i.e. steel) or sectors (i.e. energy) which were more frequently the focus of trade policy or basic research investments. Fourteen individual MIIs were designated between 2012 and 2015.

By 2018, the NNMI evolved into a federal programme that: i) invests in basic technology; ii) sites those investments within newly formed regional technology institutes (MIIs); and iii) works to link technological development to industrial capacity and, ultimately, job growth. In addition to disrupting previous innovation policy approaches by focusing on regional innovation systems, the MIIs were all initiated around technologies rather than industries. Among the targeted technologies are several often identified as "disruptive", including additive manufacturing, digital design in manufacturing, flexible electronics and biopharmaceuticals.

Table 3.4. Manufacturing Innovation Institutes in the United States

Manufacturing innovation institutes	Targeted technology	Primary city	State	Year
National Additive Manufacturing Innovation Institute (AmericaMakes)	3D printing and additive manufacturing	Youngstown	Ohio	2012
Digital Manufacturing and Design Innovation Institute (DMDII)	Digital manufacturing	Chicago	Illinois	2014
Lightweight Innovations for Tomorrow (LIFT)	Lightweight materials	Detroit	Michigan	2014
American Institute for Manufacturing Integrated Photonics (AIM Photonics)	Photonic integrated circuits	Albany	New York	2015
Flexible Hybrid Electronics Manufacturing Innovation Institute (NextFlex)	Flexible electronics	San Jose	California	2015
Next Generation Power Electronics Institute (PowerAmerica)	Wide-bandgap semiconductors	Raleigh	North Carolina	2014
Institute for Advanced Composites Manufacturing Innovation (IACMI)	Composite materials	Knoxville	Tennessee	2015
Advanced Functional Fabrics of America (AFFOA)	Textiles	Cambridge	Massachusetts	2016

Advanced Tissue Biofabrication Manufacturing Innovation Institute (ATM-MII)	Regenerative medicine and tissue engineering	Manchester	New Hampshire	2016
Clean Energy Smart Manufacturing Innovation Institute (CESMII)	Smart sensors and digital process controls	Los Angeles	California	2016
National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL)	Biopharmaceutical	Newark	Delaware	2016
Advanced Robotics Manufacturing (ARM)	Robotics, AI and automation	Pittsburgh	Pennsylvania	2017
Rapid Advancement in Process Intensification Deployment (RAPID)	Process intensification and modularisation	New York	New York	2017
Reducing Embodied-energy and Decreasing Emissions (REMADE)	Design for reuse and remanufacturing	Rochester	New York	2017

Source: Clark, J. (2018[161]), "From theory to practice: What policies can prepare regions for the challenges and opportunities associated with disruptive technologies?", Background Report for an OECD/EC Workshop Series on Broadening Innovation Policy: New Insights for Regions and Cities, OECD, 22 November 2018, Paris.

In Sweden, RI.SE is an example of a centre providing applied innovation infrastructure (Box 3.16). The EU has a strong strategy for scientific research infrastructure but innovation infrastructure may be lacking. Innovation infrastructure is essential for innovators to reduce risk, reduce time to market and connect different innovation ecosystems to explore complementarities. Establishing an innovation infrastructure strategy by fostering the creation and connection of organisations like RI.SE across the EU can be a "functional equivalent" to the megacities mode from China and the United States. Megacities provide a space for exploring new ideas and innovation complementarities across a diversified industrial base and skillsets. Strengthening and scaling initiatives such as the Vanguard Initiative (2016[156]) is an example of an approach to link fragmented innovation ecosystems and infrastructures.

Box 3.16. RI.SE innovation infrastructure, Sweden

RI.SE is an independent state-owned institution in Sweden providing innovation infrastructure in different regions, in the form of a broad range of testbeds, laboratories and demonstration centres with real-life conditions. It employs 2 700 people, 30% of whom hold PhDs and manages over a 100 testbeds and demonstration facilities that are open to businesses and higher education institutions. The purpose of the organisation is to be profit-driven but not to pay dividends to the shareholder, re-investing its profits. The revenue streams of the centre accrue primarily from conducting industrial research in collaboration with firms and universities and by providing testing facilities, certification and training. A large proportion of customers are SMEs that are responsible for approximately 30% of RI.SE's revenue.

RI.SE's regional presence has spread, growing organically based on the business needs of local communities, with regional nodes giving local agents access to national infrastructure. The organisation has offices, testbeds and demonstration environments in 11 cities. RI.SE works with local governments to develop regional innovation strategies, helping to co-ordinate policies across different layers of government, finding complementarities and avoiding overlaps. RI.SE's co-ordinating role is especially relevant within complex and highly fragmented innovation ecosystems where a multitude of actors and programmes target different sectors or innovation-related activities, often leading to duplication of efforts or negative interactions. RI.SE is often the only national actor with a regional presence that helps to make national input available at a local level to universities and firms.

Source: RI.SE (n.d.[163]), *Homepage*, https://www.ri.se/en (accessed 24 April 2019).

Innovation districts

The innovation districts approach consists of having cities or regions themselves managing disruptive innovation. Through a combination of development incentives (or facilitated permitting and certifications) for private enterprise and strategic investments in public sector deployments, regions can push the implementation of the enabling platforms and systems required for the diffusion of disruptive innovation. Cities can tailor how that diffusion happens by minimising the extraction-oriented revenue models that can compromise privacy, safety or security of citizens such as through targeted regulations of data and connectivity.

Since 2010, a wave of local philanthropic investments has increasingly targeted capacity-building in urban and regional governments to address the application of disruptive innovation in cities. In the private sector, the promise of disruptive innovation relates to productivity and growth. In the public sector, the promise of increasing productivity of public services is also appealing. The potential to provide city services more sustainability, more efficiently and more equitably is particularly promising. Concerns about city-scale responses to climate change have increased interest in developing and diffusing urban policies for resilience planning.

Many urban innovations in the interest of municipal authorities attempt to leverage the same disruptive technologies that drive interests in the private sector. Necessary deployments require many of the same interventions and platforms that the private sector requires in terms of data and connectivity. Such innovations include municipal wireless, small cell deployments, environmental sensor arrays (array of things), electric charging stations, smart cities testbeds, 5G and autonomous vehicles.

In Korea, the city of Daegu has been pursuing multiple investments to manage the introduction and diffusion of electric vehicles and beyond to autonomous vehicles (Box 3.17). Many large cities such as Boston, Chicago and New York (United States), London (United Kingdom) or Paris (France) have identified the need for increased internal expertise in disruptive technologies and the analytical ability to understand how they might affect the management and administration of city services and operations. Often local governments did not have the resources to invest in the expertise required in the wake of the public sector downsizing exacerbated by the 2008 recession, collaborating with the private sector for seeding capacity within through “innovation delivery teams” and resilience officers (Clark, 2018[161]).

Box 3.17. Electric Vehicle Leading City, Daegu, Korea

The Metropolitan City of Daegu in Korea has been adapting to disruptive technologies promoting industrial rejuvenations both through the demand and through the supply side. The city was a traditional textile manufacturing hub that gradually moved to auto parts and machinery production. With the 2016 “C-Auto” mid- and long-term comprehensive plan, the Metropolitan City of Daegu decided to aggressively pursue a strategy to establish the city as a leader in electric vehicles.

The strategy involved infrastructure investment in charging stations, subsidies to the producer as well as consumers. To start the local production, the city focused on cargo delivery vehicles (both four- and two-wheelers) and supported strategic partnerships between domestic logistics and delivery companies, local electric vehicle producers and in particular local start-ups (Zein Motors and Green Mobility). Investment in charging infrastructure, production infrastructure and subsidies for the purchase of electric vehicles is combined with additional monetary incentives (reduced fares on toll roads, reduced parking fees, support for charging fees and various other tax cuts) and regulatory support for electric vehicles. The efforts have led to Daegu having the highest rate of new electric vehicles per capita in Korea (in 2019) and winning the Korean brand award as “Electric Vehicle Leading City” two years in a row (2018 and 2019).

The ambition of the Metropolitan City goes beyond electric vehicles. With the Daegu International Future Auto EXPO and investment in research and testing infrastructure, the city aims to build an ecosystem for autonomous vehicles.

Source: Daegu (2019[164]), http://info.daegu.go.kr/mnews/view.php?key3=238650; MK (2018[165]), "Zein Motors opens Korea's 1st electric truck production factory", https://www.mk.co.kr/news/english/view/2018/05/314069/.

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Notes

[1] See http://data.worldbank.org/about/country-and-lending-groups (accessed 5 August 2019) for the World Bank classification of countries by income level.

[2] See https://www.rand.org/topics/delphi-method.html (accessed 21 August 2019).

[3] See Bosetti et al. (2012[169]) for a survey design that aims to test and minimise bias.

[4] The discussion of regional characteristics follows Koutroumpis and Lafond (2018[11]).

[5] See OECD (2018[151]) for details.

[6] Total consumption for aluminium production was14 334 kWh in 2016 and total overall consumption 18 059 kWh according to Statistics Iceland, https://px.hagstofa.is/pxen/pxweb/en/Atvinnuvegir/Atvinnuvegir__orkumal (accessed 13 August 2019).

[7] Calculations based on UN COMTRADE data for 2018, https://comtrade.un.org/data (accessed 13 August 2019).

[8] Based on Statistics Iceland, https://px.hagstofa.is/pxen/pxweb/en/Atvinnuvegir/Atvinnuvegir__orkumal (accessed 13 August 2019).

[9] Southern-Kanto (12.1%) and the Kansai region (4.9%) in Japan, Guangdong (7.9%) in the People's Republic of China, California (7.1%) in the United States and Korea's Capital Region (4.9%). Calculations based on OECD Regional Statistics (database), https://doi.org/10.1787/region-data-en (accessed 13 August 2019). The shares slightly overestimate the total as only OECD countries with TL2 regions and large patenting countries are considered. The OECD database includes slightly more than 208 000 Patent Cooperation
Treaty (PCT) patents for 2015 whereas the global total was about 218 000, https://www.wipo.int/export/sites/www/ipstats/en/docs/infographics_pct_2015.pdf (accessed 14 August 2019).

[10] MIT OpenCourseWare Site Statistics and Monthly reports, https://ocw-origin.odl.mit.edu/about/site-statistics/ and https://ocw-origin.odl.mit.edu/about/site-statistics/monthly-reports/ (accessed 14 August 2019).

[11] The project won the 2018 Regio Stars Award in the category "Smart Industrial Transition", https://ec.europa.eu/regional_policy/en/projects/portugal/business-and-shared-services-centre-supports-smart-growth-in-portugals-centro-region (accessed 13 August 2019).

[12] The chapters are Culture, Entrepreneurship and Growth (Doepke and Zilibotti, 2014[170]), Trust, Growth and Well-Being: New Evidence and Policy Implications (Algan and Cahuc, 2014[168]) and Family Ties (Alesina and Giuliano, 2014[167]).

[13] The shares refer to the "main component" of the co-patenting network, i.e. the largest, weakly connected component of the network of co-patenting inventors. Casper (2009[120]) considers both direct co-patenting relationships, i.e. two or more inventors that file a joint patent and indirect relationships. Indirect relationships link inventors that do not co-patent themselves but have a joint co-inventor with whom they filed separate patents (with patents being filed no longer than five years apart).

[14] The study measures general-purpose technologies (and other technologies) using patent data. The definition of general-purpose technologies follows the EC's "key enabling technologies" (Vezzani et al., 2014[172]). They are: i) nanotechnology; ii) photonics; iii) industrial biotechnology; iv) advanced materials; v) micro- and nano-electronics; vi) advanced manufacturing technologies.

[15] In addition larger cities also provide those individuals with stronger skills greater opportunities to learn and increase the economic returns to their skills (Roca and Puga, 2017[171]).

[16] These systems of cities can span large distances and form "megaregions" connected through infrastructure, economic connections, settlement patterns and land use, topography, an environmental system or a shared culture and history that together shape a common interest for the wider region (Glocker, 2018[166]).

[17] The OECD is working towards the development of general principles for enhancing access to and sharing data across the economy in a coherent manner, https://www.oecd.org/internet/ieconomy/enhanced-data-access.htm (accessed 24 July 2019).

[18] Interreg Europe helps regional and local governments across Europe to develop and deliver better policy. Interreg Europe has a total volume of EUR 359 million for the 2014-20 period and co-finances up to 85% of project activities that are carried out in partnership with other policy organisations based in different countries in Europe.

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