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The Fourth Industrial Revolution and implications for innovative cluster policies

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Abstract
The Fourth Industrial Revolution has become a global buzz word since the World Economic Forum (WEF) adopted it as an annual issue in 2016. It is represented by hyper automation and hyper connectivity based on artificial intelligence (AI), big data, robotics, and Internet of things (IoT). AI, big data, and robotics can contribute to developing hyper automation that can increase productivity and intensify industrial production. Particularly, robots using AI can make decision by themselves as human being on complicated processes. Along with the hyper automation, the hyper connectivity increases not only at national, but also global level by using information and communication technologies (ICT). IoT is the core technology to create the hyper connectivity in Cyber Physical System (CPS) that connects technology, nature, and human being. Accordingly, a perfect convergence between ICT and manufacturing can be completed in the Fourth Industrial Revolution era and an extremely efficient flexible production system by spreading IoT in CPS will be established. Under such a condition, innovative clusters must play their traditional roles in cradles of technology innovation and commercialization. It must be difficult challenges for innovative clusters to meet their targets and to be adjusted by the changing new environment at the same time. This paper argues how the Fourth Industrial Revolution can change the global production chain and how core technologies function in industries. Furthermore, it focuses on how innovative clusters have to evolve to respond the Fourth Industrial Revolution. Last, but not least it also analyzes whether or not innovative clusters can play their roles as technology innovation hubs in the real world and CPS in the Fourth Industrial Revolution era.

Keywords Fourth Industrial Revolution · Hyper automation · Hyper connectivity · CPS · Innovative cluster policies

1 Introduction

Prior to industrial revolutions, human being had centered around improvements in automation and connectivity in order to strengthen productivity. In line with such activities, the First Industrial Revolution introduced early automation through machinery and developed intranational connections through building of bridges and railways. In 1784, Henry Cort's invention in England of the puddling process was able to turn pig iron to wrought iron. It was regarded as a key inflexion point of the First Industrial Revolution making automation. Furthermore, mechanization for automation became a key element of economic development that led to a profound split between the East and West in economic history. In addition to manufacturing progress, the use of higher-energy intensive fuels such as coal and petrol paved way for stream power and locomotives that created connectivity revolution.

The Second Industrial Revolution beginning around 1870 generated higher level of automation via the development of mass production and more efficient connectivity in production via the division of labor. It also made further progress in use of energy sources such as electricity and petroleum. During the Second Industrial Revolution, developed automation and connectivity allowed supply chains expanding rapidly across different companies and increasingly between different nations. Standardization including quality standards and transport system such as trade blocks and shipping container was the key drivers of these achievements. Additionally, legal and trade protections were created in order to assure innovators enjoying financial rewards of their creativity that

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may not be exposed to early competition from rivals copying their technologies.

The Third Industrial Revolution began in 1969 with the rise of digital age that is of more sophisticated automation, and of increasing connectivity between and within humanity and the natural world. The digital age enabled connectivity taking a leap forward after sending the first message over ARPANET, the early generation of today's Internet. At the same time, the scope for automation was also strengthened by the implication of Moor's Law that the number of transistors on an integrated circuit could be doubled every 2 years. It resulted in greater computing power and the ability to automate more complex tasks in production (Baweja et al. 2016).

Since 2010, new phenomena have raised based on extreme automation and connectivity represented. It is a special feature that will be a wider implementation of artificial intelligence (AI). AI enables big data processing including processing of languages and images which computers are not able to understand. Furthermore, AI systems can operate with increasing autonomy and capability in various areas from industries to private households. The Fourth Industrial Revolution is expected to start around 2020 by developing AI, Internet of things (IoT), big data, and robot. Accordingly, hyper automation allows more robots and AI to produce outputs and analyze results. Additionally, it also makes complex decisions and adopts conclusions to given environmental factors. As a result, in the Fourth Industrial Revolution era, hyper automation expands the range of jobs to be automated that include not only highly repetitive low-skill jobs, but also highly routine medium-skill jobs. Unfortunately it may be possible that it will intensify income inequality between low-skill and high-skill jobs (Schwab 2016; Baweja et al. 2016; Stanford University 2016; Gill 2017).

The Fourth Industrial Revolution also creates hyper connectivity based on monitoring, analyzing, and digitizing that impact how to connect between human and machine, human and human, and machine and machine. As a result, hyper connectivity makes possible more universal, global, and close to instant communication. It could open up economy supply that was not possible previously. Extreme automation and connectivity represent a democratization of the ability to communicate between and among governments, firms, humans, and machines that enables to emerge cyber physical system (CPS), in which the techno-sphere, the natural world, and the human world are connected.

In line with the Fourth Industrial Revolution or industry 4.0, innovative clusters try also to shape smart industry complexes in order to meet new trends toward mass customization and servitization. Innovative clusters are regarded as the hub of startups generating technology innovation as well as new products and processes that creates an innovative habitat. The key question is how to effectively use innovative clusters to capitalize upon new technologies and service offerings that result from the digitalization and industrial transformation trends. In the new trends, innovative clusters must deal with everything becoming interlinked and smart between factories, machines, autonomous production systems, and the actors along the value chains. These are great challenges for innovative clusters in the future because the smart production system based on hyper automation and connectivity could overcome geographical boundaries and enable to carry out production activities within the markets. At the same time, innovative cluster policies must respond to these new industrial challenges through facilitating cross-sectoral value chains, strengthening internationalization, boosting interregional investments, and accelerating entrepreneurship and further skill upgrading.

This paper aims to explain how industrial revolutions have been evolved and explore the real meaning of the Fourth Industrial Revolution. Furthermore, it focuses on how innovative clusters respond to the new industrial transformation trends in order to develop further in new environment. Last, but not least, it analyzes what innovative cluster policies contribute to strengthening competitiveness of innovative clusters in the EU and how to prepare for the Fourth Industrial Revolution era.

2 Theoretical debates

Schumpeter already introduced the idea of innovation economics in the mid of the twentieth century. In his idea, evolving institutions, entrepreneurs, and technological change were at the heart of economic growth and not independent forces that were largely unaffected by public policy. Particularly, innovation economics emphasizes entrepreneurship and innovation that creates innovative destruction and generates new economic growth. Hence, it focuses on economic creativity that affects the theory of firms and organizational decision making. As a result, innovation economists urge that economic growth in the knowledge-based economy is mainly driven by innovative capacity resulted from appropriate knowledge and technological externalities instead of capital accumulation as explained by neoclassical economic growth theory (Schumpeter 1942; Acs 2006).

Despite different views and approaches of economic growth, it is common that contemporary models of economic growth are based on investment and knowledge as the prime source of economic development. However, growth performance can vary across nations, although the nations may have similar knowledge endowments and institutional design. In the knowledge-based economy, entrepreneurial startups play significant roles in knowledge creation and commercialization that generates economic growth (Karlsson and Nyström 2009).

The knowledge-based growth model known as an endogenous growth model appeared in the mid of the 1980s. In this model, investments in knowledge and human capital were made by profit maximizing firms in a general equilibrium. As a result, firms investing in R & D created competitive edge over their competitors. Additionally, parts of that knowledge spilled over to a societal knowledge stock that influenced the production function of other firms and increase their productivity. The endogenous growth model emphasized the influence of knowledge spillovers on economic growth. The core point of the model was that the role of knowledge plays in making economic growth possible. However, it had its limitation to specify how knowledge could be spilled over. Therefore, it was a critical issue in the knowledge-based growth model how to spillover knowledge created by heavy investment in R & D that must be converted into goods and services. It was basically unknown in the model (Romer 1986; Lucas 1988; Rebelo 1991).

In order to cope with the limitation of the endogenous growth model, the neo-Schumpeterian designed R & D races where a part of R & D turns into successful innovations. This explanation could remedy the limitation to some extend and imply a step forward. However, the essence of the Schumpeterian entrepreneur was still missed. In fact, the innovation processes use to be far more complex than R & D races that involve various incumbents and focus on quality improvements of existing goods and services (Schmitz 1989; Segerstrom 1991; Aghion and Howitt 1992).

In the most recent knowledge-based growth model, the effects of technology-based entry on the innovativeness, productivity, and the implications of firms' heterogeneity on creative destruction and growth are predominantly focused. The new element of the recent model is to take into account the effects of competition and innovation of both incumbents and new firms. In addition, the recent model urges that entry or entry threats can have positive effects on the innovative behavior by incumbents being closed to the technological frontier. However, such effects are not expected by technological laggards. The new economics known as new growth economics, neo-Schumpeterian economics, and innovation economics etc. reformulates the traditional economic growth model such that knowledge, technology, entrepreneurship, and innovation are regarded as core elements that play as forces in operating interdependently one another. Accordingly, self-sustainable economic growth is possible in the knowledge-based economy. The web economy is a specific manifestation of the primarily knowledge-based economy (Aghion and Griffith 2005; Aghion et al. 2006; Dosi 2012).

Particularly, entrepreneurial activities have positive effects on economic growth in highly developed countries, while these generate negative effects in developing countries. Furthermore, investing in economic capabilities that strengthen firm's ability to innovate and compete not only on domestic market, but also global market has become an important issue that national and local policies focus on. The ability to generate economic growth also depends on decision makers' understanding of how to contribute to innovative economies. In the decision-making process, the government plays important roles in supporting economic growth because the long-term economic growth relies on active intervention in support of innovation, entrepreneurship, production, workforce development that are mainly microeconomic concerns (Acs 2006; Feldman and Lowe 2017).

This paper adopts the most recent knowledge-based growth model with evidence-based economic development policy. In this background, technology, innovation, entrepreneurship, and government policy creating the Fourth Industrial Revolution can be explained and upgrade innovative clusters dealing with smart industry complexes.

3 The Fourth Industrial Revolution

3.1 Background

The Fourth Industrial Revolution, known as Industry 4.0 in Germany in the early 2010s, is currently debated in the economic literature, and academics try to make reasonable projections how it leads to the future. In reality, however, the views on the Fourth Industrial Revolution are rather diverse. Some argue that the Fourth Industrial Revolution cannot imply the strong growth potential that was generated by the previous industrial revolutions. Other claim that the impacts of the Fourth Industrial Revolution will be stronger than ever along with the ongoing digitalization on technological innovation that generates economic growth (Gordon 2014; Brynjolfsson and McAfee 2014).

Among the theorists, Schwab represents positive and drastic impacts of the Fourth Industrial Revolution and predicts changes in how we work, live, and do business. He explains that the change will be historic in terms of their size, speed, and scope. The drivers of change are physical, digital, and biological. The physical change is made by autonomous vehicles, 3D printings, robots, and new materials, while the digital change is carried by IoT and Internet of services (IoS). The biological change can be realized by generic sequencing, generic engineering, and synthetic biology and biological editing. Even at present, technological transformation has strongly influenced every aspects of economic and social life that include basic mechanisms like demand formation, capital accumulation, employment generation (Schwab 2016; Dosi 2012).

3.2 Characteristics and meaning

The term of the Fourth Industrial Revolution became widely known at the Hannover Fair in 2011 that referred to the Industry 4.0 as a part of High Tech Strategy 2020 in Germany. It aims to establish Germany as an integrated industry leader and market provider. The Industry 4.0 focuses on redesigning manufacturing and production processes that would shift from a centralized to a decentralized model based on ICT-based systems. Under the Fourth Industrial Revolution, the growing digitization of productions and processes in the global economy has triggered far reaching changes not only in firms, but also in societies. These changes are not regarded as machines of transactional efficiency, bureaucratic order of labor exploitation. In fact, these changes affect to repositories of competencies, knowledge, and creativity in firms and societies. Accordingly, the term of the Fourth Industrial Revolution refers to technologies and concepts of value chain organization as the European Commission set a path to digitize European industries (Eckart 2016; EC 2016; Amin and Cohendet 2012).

It is clearly distinguishable in four waves of industrial revolution. The first wave at the end of the eighteenth century was characterized by using water and steam power to industrialize mechanical production. The second wave at the end of nineteenth century and the beginning of the twentieth century combined the use of electric energy and new production methods, while the third wave automated production by using digital technologies and computing power. In twenty-first century, the fourth wave just started with AI, big data, IoT, and robot. The Fourth Industrial Revolution has triggered decisive impacts on every industry although there are still debates whether the current transformation can be considered as the Fourth Industrial Revolution or an acceleration of the Third Industrial Revolution and the digital conversion. Despite such diverse views on the Fourth Industrial Revolution, the fusion of the physical and the virtual world into cyber and physical systems (CPS) change production and process as cross-functional and interdisciplinary. These systems are a consequence of far reaching integration of production, sustainability, and customer satisfaction based on intelligent network systems and processes. As a result, the efficiency of traditional hierarchical structures and centralized decision making in organizations could face difficulty, while digital collaboration gains its importance substantially (Bloem et al. 2014; Staffen and Schoenwald 2016) (see Fig. 1).

Technological transformation changes practically every aspects of economic and social life. It also changes market structures and firms. Changing market structures appear to two or multi-sided markets and platform economics. These markets clearly distinguish groups of users, and their demands are interdependent that generate positive

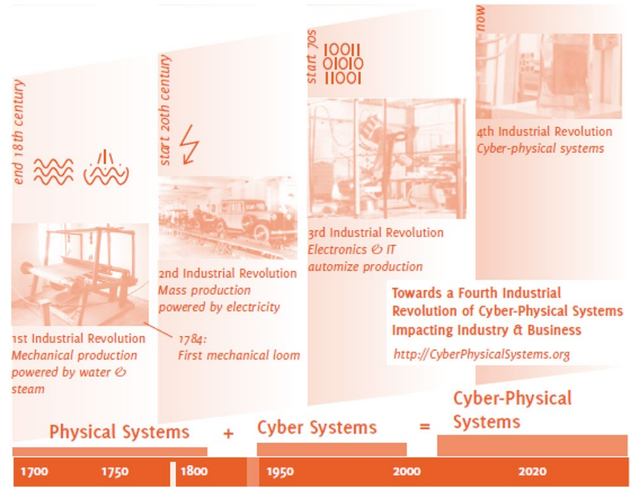

Fig. 1 The Fourth Industrial Revolution and cyber and physical system Source: Bloem et al. 2014

externalities. In fact, many industries operate as two sided markets at present. In this condition, platforms such as exchange, media, transaction system, and software platforms can ensure room for interacting among different groups so that it plays significant roles in reducing transaction cost (Evans 2011).

Under the Fourth Industrial Revolution, firms appear as a cognitive platform for interacting communities and complete their business ecosystems based on corporate culture and common knowledge. These are dynamic and coevolving communities of diverse actors creating new value through cooperation and competition. In these systems, new value is not created linearly in the value chain, but sustainable in a network structures called as the value web. As a result, the business ecosystems materialize synergy effects that make firms attractive regardless of small or big (Canning and Kelly 2015).

In addition to market structures and firms, the Fourth Industrial Revolution transforms manufacturing that is the foundation for building economic prosperity in industrialized nations and a tool to support national development goals. Since the late twentieth century technology and innovation play significant roles in driving forces for economic growth and upgrade their capabilities constantly. As a result, the manufacturing evolves through global economic dynamics and advanced equipment as well as processing technologies in order to produce more diverse and sophisticated products. It will affect not only employment based on high skill levels with high wages, but also a great convergence of skills. Therefore, it is significant to understand changes in manufacturing that enables national economies to establish their own capabilities generating new development opportunities. The future of manufacturing relies on how to develop capabilities that add value in an economy (WEF 2016a).

Highly developed automation and connectivity make possible smart products and services that minimize barriers between manufacturing and service industries. Smart products and services connected to the Internet during the operation will form the basis of new data and service-based business model. It will create new value chains and networks based on digital industrial convergence and alliances. In the smart system, the ability to rapidly translate alliances and efficient forms of cooperation is regarded as a key competitive advantage. In such a habitat, startups play an innovative role, while manufacturers shape value networks for their own interests and promote the ecosystems. Combinations of smart products and services can create flexibilities to allow every product as services whenever they are required. It also needs that manufacturer and intermediary acquires to understand their customers' needs and lives profoundly (Kagermann et al. 2014).

3.3 Socioeconomic implications and people dimensions

The implications of the Fourth Industrial Revolution are wide ranging and complex in businesses, governments, civil society organizations, and people that is regarded as a systemic change of nature. These range from practical to ethical considerations as well as from monetary to societal consequences. The Fourth Industrial Revolution regarded as a megatrend does not generate only positive aspects such as improving quality of life, but also negative aspects such as challenges and risks of income inequality. Accordingly, it will create profound impacts of disruptive change on industries and employment structures (Balogh 2017; WEF 2016b).

Production has become more automated by using intelligent machines so that the advantage of low cost of human labor supply has declined. It means that a share of jobs has increasingly become re-shored to its original location that causes a negative effect on labor intensive production-based economies. Additionally, a labor market transformation results in heightened productivity levels and widening skills gaps that displace jobs to a larger extend than generating new ones. Given the World Economic Forum's estimation, approximately two-thirds of disrupted jobs are white color office functions that must be prepared for new skills requirements of the future. Furthermore, about 65% of children entering primary schools today will work in new areas that do not exist at present. It indicates that education systems embracing technological advancements are the most important element to contribute to socioeconomic development effectively (WEF 2016b).

The changing patterns of manufacturing could disrupt the labor market as well. However, at the same time, these will also create new opportunities for companies to improve products and services that enable to boost consumption in a more sustainable manner because companies could explore customers' behaviors through digital technologies, data analytics, and connectivity. This creates more collaborative innovations that serve better to the knowledge-based society. Sustainability is the key word of the Fourth Industrial Revolution. Environment-friendly technologies called as green technologies, energy efficiencies, and renewable materials in production are able to increase productivity to nations and enhance global resource security that mitigate risks of global climate change in the end. In reality, the creation of a green infrastructure requires a vast initial capital investment from governments and companies. However, it is also true that such an investment can generate significant returns in terms of direct and indirect effects (Balogh 2017).

The Fourth Industrial Revolution also creates negative aspects at a broad level. The embeddedness of Internet affecting to our lives in the next industrial revolution era will enhance the growing level of inequality that has existed as socioeconomic trends. The reason for it is that more than one-half of the world population has no access to Internet in 2015. Therefore, income inequality based on the information asymmetry will continue to be widened between nations, communities, and individuals if the diffusion of innovation is not governed properly (OECD 2011; Schwab 2016).

In addition to the socioeconomic aspects such as disruptive changes in production and information processing, the Fourth Industrial Revolution will transform human dimensions as well. It revolutionizes the daily work of employees on all hierarchical levels. In particular, the five people dimensions such as leadership, new skills and talent, organization, work environment, and ways of working can be changed drastically and most affected. The leadership will become tomorrow's game changer by embracing the disruptive changes and encouraging their employees to do the same. Leaders are not only digital experts, but also master various roles in entrepreneurs, strategists, and vision providers. On the employee level, new skills and talents are required. In this regard, on the one hand, entirely new job profiles are required, and on the other hand, existing employees need to be supported in developing new skills. Traditional and hierarchical organization structures cause conflicts with a high demand for interdisciplinary collaboration to strengthen corporate innovation. Therefore, organization structures need to reduce hierarchical structures because decision-making processes become more flexible than ever. Work environment based on employee mobility and flexibility shape inevitably, and ways of working within project teams become more usual than departmental boundaries (Staffen and Schoenwald 2016) (see Fig. 2).

Therefore, it is necessary to pay attention when all actors such as governments, communities, companies, and individuals set their strategies to deal with the Fourth Industrial

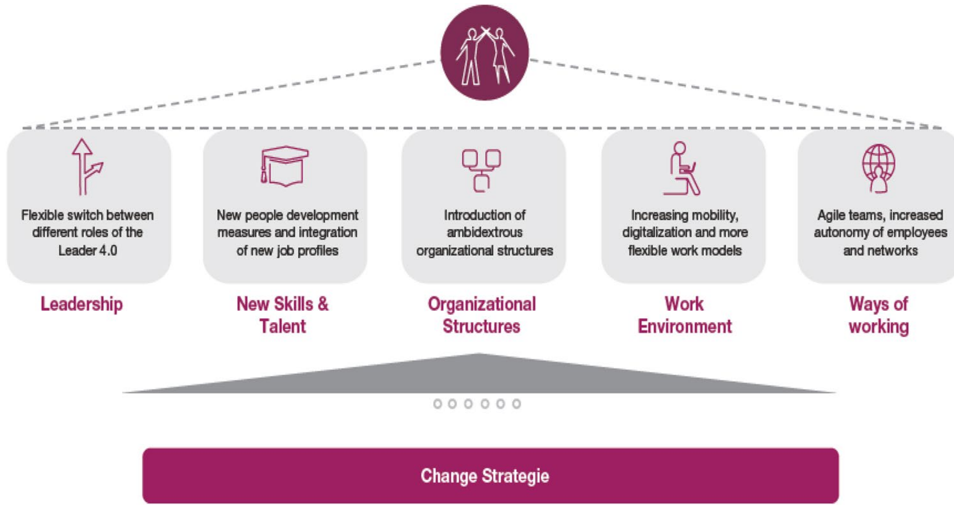

Fig. 2 People dimensions in the Fourth Industrial Revolution Source: Staffen and Schoenwald 2016

Revolution. The common sense is that the human dimension of a digital era is regarded as challenging as the technological dimension.

4 Future of manufacturing in the Fourth Industrial Revolution

4.1 Key drivers of future manufacturing

As explained above, manufacturing in the Fourth Industrial Revolution has become so complex that it has to ensure its effective development. Under such a circumstance, the interests of private sector, public sector, and civil society are often converged. Given the study of Global Agenda Council in the World Economic Forum, there are ten key drivers identified based on convergence and divergence of needs for the private and public sectors as well as civil society in different countries. These ten key drivers will shape the future of manufacturing and are categorized by the two different sectors such as capabilities as well as policies and trends. The former are advanced data analytics, cyber physical production, circular economy and remanufacturing, additive manufacturing, and cross-domain skills, while the latter are global value chains, servicification, industrial policy, manufacturing regionalization, and digital infrastructure (WEF 2014) (see Fig. 3).

Beyond the ten key drivers, a broader shift in manufacturing can take place that will impact on the sector fundamentally. As the previous industrial revolutions, the Fourth Industrial Revolution will also come in waves and cycles of technological innovations that creates new opportunities for manufacturing and becomes increasingly complex. Such a shift will integrate impacts of the Fourth Industrial Revolution and stands out a broad scale of change. Therefore, business and government leaders in the private and public sectors as well as leaders in civil societies must assess their market positioning and readiness for the disruptions. Accordingly, a better understanding of dynamics of a broader shift is absolutely needed particularly for manufacturing companies to

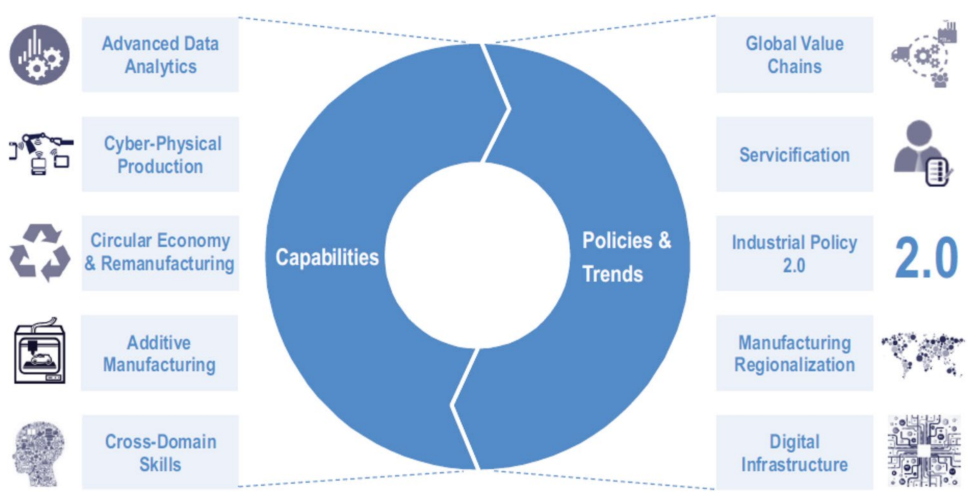

Fig. 3 Ten key drivers for the future of manufacturing Source: Global Agenda Council 2014

maintain their competitiveness and seize new opportunities (WEF 2016a).

4.2 Transformation of the future manufacturing

Digitalized future manufacturing will cause a wide range of changes to manufacturing processes, products, and business models. Smart factories regarded as the model of future manufacturing enable to create increased flexibility in production. Automation in the production process, the transmission of data about products, and the use of configurable robots can make possible that a variety of different products can be produced in the same production facility. The high level of flexibility enables a mass customization that allows the production of small lots with the ability to configure machines rapidly by adapting to customer supplied specifications and additive manufacturing. In addition, the high flexibility encourages product innovation continuously because new products can be produced rapidly without setting the new production lines (Davis 2015).

The speed of production will also improve because digital designs and virtual modeling of production process reduce the time for designing products and their deliveries. Data-based supply chains can increase the speed of manufacturing process by an estimated 120% in terms of time for delivering orders and by 70% in time for delivering products to markets. Furthermore, integrating product development with digital and physical production has improved product quality and at the same time reduced error rates because data from sensors is used to monitor every parts and components produced rather than using sampling to detect errors. As a result, the increase in product quality can play a significant role in reducing production costs and upgrading competitiveness (Davis 2015; Strategic Policy Forum on Digital Entrepreneurship 2015).

Productivity will also increase by using advanced analytics in predictive maintenance programs. Manufacturing companies can avoid machine failures in production facilities and reduce downtime by an estimated 50%. At the same time, they can increase productivity by 20%. In Germany, the impact of Industry 4.0 can be estimated by productivity improvements on conversion costs ranging 15–25% that exclude the cost of materials. If the material costs are included, the productivity gains can be achieved from 5–8%. Additional revenue growth will be about Euro 30 billion per year that accounts for roughly 1% of German GDP. Moreover, the Industry 4.0 will generate the 6% increase in employment in manufacturing sectors (Rüssmann et al. 2015).

In addition, consumers can be more involved in the design process that makes products faster and cheaper than before. With the transformation of relationships between producer and consumer as well as a high level of automation of manufacturing, the location of some manufacturing can be close to the customer that can bring manufacturing capacity re-shored instead of off-shored. Last, but not least business models will be changed radically. Manufacturing companies compete on the basis of innovation in order to deliver new products rapidly and on the ability to produce customer driven customized designs rather than compete on the cost. Additionally, a high quality for reducing faults due to automation and control can be the core target for manufacturing companies to compete with others. As a result, some companies enable to create smart products by using big data and adopt new business models for selling services instead of products that is called as servitization of manufacturing. They are able to offer combined digital and physical operation as a service. Such a servitization can create new business opportunities for manufacturing (Davis 2015; Strategic Policy Forum on Digital Entrepreneurship 2015; Kagermann et al. 2014).

4.3 Challenges of the future manufacturing

It is true that all observers are not convinced the value of the Fourth Industrial Revolution. However, the Gartner Group as a world leading research and advisory company issued a special report on the hype cycle for emerging technologies in 2014. It indicates that many of the core technologies for the Fourth Industrial Revolution are evident to be applied for the broad market in 5–10 years. Despite the fact, there are several barriers ahead that make the future of manufacturing challenged (Rivera and van der Meulen 2014).

Investment and change are the first challenge. In order to build a complex value network, business leaders have to accept to change not only suppliers and distributors of products, but also technology companies and infrastructure suppliers. Companies even need to cooperate with their competitors in order to use standards that allow the transmission and exploitation of large quantities of data. Large amounts of investment in digital infrastructures are challenging many nations. Even Germany needs to invest Euro 40 billion per annum until 2020, and EU as a whole has to invest Euro 140 billion per year. Therefore, some criticize that the industry 4.0 costs extremely high and its approach is driven not by consumer demand, but by equipment producers. Despite such a high cost and various critics, digital infrastructures are absolutely needed in order to realize smart factories that generate new business models and value added (Davis 2015; Kagermann et al. 2014) (see Fig. 4).

Furthermore, data ownership and security are significant challenges for the future manufacturing because a large quantity of data can be collected and shared with partners in value networks. Therefore, it is necessary that businesses must clarify who owns what industrial data, and how to be confidential between competitors and collaborators. In order

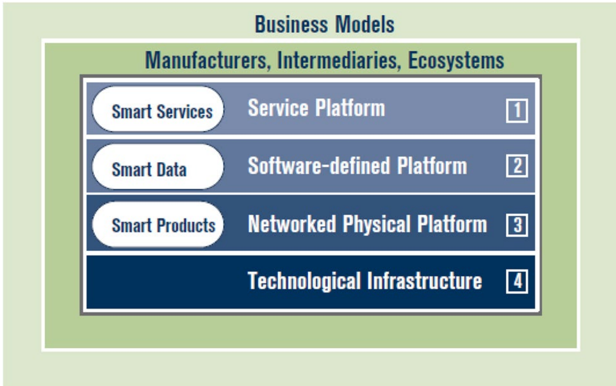

Fig. 4 Layer model of digital infrastructure Source: National Academy of Science and Engineering (ACATECH) 2014

to overcome the challenge, smart services will be based on the data created by smart devices during manufacturing and using. In addition, rules on privacy, data storage, and copyright must balance trust and data protection. Legal issues are also challenging because advanced manufacturing raises various legal questions such as employee supervision, product liability, and intellectual property rights (IPRs). In order to deal with legal issues properly, it is also needed to balance between the stimulation of innovation by protecting IPRs and the sharing of knowledge that are both basic sources for future progress (Davis 2015; Fontagné et al. 2014).

Standards are also important issues. These are essential to ensure the exchange of data between machines, systems, and software within a networked value chain because a product moves into the smart factory toward completion. However, if data and communication protocols are recognized domestically, competition and international trade cannot increase and trade costs will rise. Therefore, international standard communication protocols, data formats, and interfaces are needed in order to ensure interoperability across different sectors and different nations that enable to create open markets worldwide. Last, but not least employees and skills development are challenging areas. Employees with low skill levels will have high risk to be replaced by advanced robots unless they are retrained properly. At the same time, employees with high skill levels will enjoy high autonomy at their working places. Particularly employees with creativity and decision-making skills as well as ICT expertise are needed to overcome these challenges (Davis 2015).

4.4 Evaluation of future readiness for the Fourth Industrial Revolution

International research organizations such as World Economic Forum (WEF) and International Institute for Management Development (IMD) assess global competitiveness in various countries in the world annually. The former publishes Global Competitiveness Report based on the three categories such as basic requirements, efficiency enhances, and innovation and sophistication factors that provides specific scores and ranks. The latter also publishes the IMD World Competitiveness Ranking and IMD World Digital Competitiveness Ranking based on knowledge, technology, and future readiness. As a global financial services company, UBS AG published a white report on extreme automation and connectivity for WEF in 2016 that indicates the global, regional, and investment implications of the Fourth Industrial Revolution. The white paper is based on the Fourth Industrial Revolution categories such as labor structure, skill level, education, digital infrastructure, legal protection, and overall impacts (WEF 2016c; IMD 2017; Baweja et al. 2016).

Human capital and technology innovation play the most important roles in a successful industrial revolution. Moreover, digital infrastructure, macroeconomic environment, education, market efficiency, business sophistication, etc. are equally important for realizing the Fourth Industrial Revolution. In order to collect data on nation's competitiveness and readiness for the Fourth Industrial Revolution, I use the three indexes such as Global Competitiveness Ranking, IMD World digital Competitiveness Ranking, and UBS Ranking that enable to judge the relative readiness of different countries to take advantage of the Fourth Industrial Revolution. In order to maximize the objectivity of the data, I make the new ranking based on the average of the three indexes.

As a result, developed economies rank on the top list. Among the top 24 most prepared nations for the Fourth Industrial Revolution, the western countries are dominated while only six East Asian countries are listed. Among the western countries, western European countries, particularly northern European countries, are highly advanced in the ranking. Moreover, all Anglo Saxon countries are also listed, and the USA and the UK play the leading roles. It means that these nations will lead the Fourth Industrial Revolution in the future (See Table 1).

5 Implications for innovative cluster policies in the Fourth Industrial Revolution

5.1 Background

Innovative clusters are regarded as powerful instruments to strengthen industrial competitiveness, innovation, and regional economic growth. Furthermore, they create technological, organizational, and process-oriented innovations that build entrepreneurial ecosystem and carry out smart specialization strategy. As a result, cluster strategies generate efficiency gains and business opportunities that individual

Table 1 High ranking nations for future readiness of the Fourth Industrial Revolution (As of 2016–2017) Source: WEF 2016a, b, c, IMD 2017; Baweja et al. 2016

Ranking	Nation	WEF	IMD	UBS AG	Average
1	Singapore	2	1	2	1.7
2	Switzerland	1	8	1	3.3
3	USA	3	3	5	3.7
4	Netherlands	4	6	3	4.3
5	Finland	10	4	4	6.0
6	Sweden	6	2	11	6.3
7	Hong Kong	9	7	7	7.7
8	UK	7	11	6	8.0
9	Denmark	12	5	9	9.7
10	Norway	11	10	8	8.7
11	Germany	5	17	13	11.7
12	New Zealand	13	14	10	12.3
13	Canada	15	9	15	13.0
14	Taiwan	14	12	16	14.0
15	Japan	8	27	12	15.7
16	Austria	19	16	18	17.7
17	Australia	22	16	18	18.7
18	Israel	24	13	21	19.3
18	Belgium	17	22	19	19.3
18	Ireland	23	21	14	19.3
21	France	21	25	20	22.0
22	Korea, Rep.	26	19	25	23.3
23	Malaysia	25	24	22	23.7
24	Spain	32	30	27	26.7

companies are not able to attain by them. Such gains and opportunities are captured by the concept of collective efficiency and defined as the competitive advantages that result from local external economies and joint actions (Schmitz 1997; European Union Regional Policy 2012).

Since the beginning of the 1990s, hundreds of cluster initiatives have been developed all over the world because the benefits of clusters for productivity and innovation have been created in the regions where innovative clusters have been operated and impacted on regional and corporate competitiveness. Cluster initiatives mean all activities among innovative actors to organize and develop linkages and networks for creating benefits of firms and other organizations in the clusters. Accordingly, these are intermediary activities and organizations within the clusters. By implementing cluster initiatives, innovative clusters foster their competitiveness proactively instead of facing natural processes to occur (Porter 1990; Solvell et al. 2003; Laur et al. 2012; Lindqvist et al. 2013).

In relation to cluster initiatives, developing business associations and excellence clusters are recommended as parts of innovative cluster policies that generate both internal and external environments for collaboration and cross-fertilization between industrial sectors and technological areas in order to diversify and modernize business structures. Innovative clusters will face difficult challenges in the Fourth Industrial Revolution era because production and process management do have little geographical barriers due to hyper automation and hyper connectivity. Therefore, innovative cluster policies have to focus to carry the smart specialization strategy not only at the design, but also at the implementation phase (European Union Regional Policy 2012; Obrégon 2015).

5.2 Innovative cluster policies in the EU

Over 3000 strong clusters are operating in the EU, which are statistically defined regional concentrations of related traded industries. These achieve higher than average performance for employees, firms, and regions. Therefore, cluster effects have become a reality when the presence of related industries in a specific location reaches a critical mass. In terms of employment, approximately 45% of all employments in traded industries based on agglomeration in specific locations are generated in the strong clusters, and the wages of employees in the strong clusters are 11% higher than employees working outside of the clusters. In the USA, a similar pattern was discovered in the 2010s that new business formation in the strong clusters is higher than average, and new firms in the strong clusters are more succeed and grow than average. As a result, the strong clusters are regarded as the innovation and growth drivers of the economy both in the EU and the USA. They generate more than 87% of all patents, and higher productivity, wages, and growth than average (Commission 2016; Delgado et al. 2010, 2014).

Innovative clusters use to emerge in market driven processes that reflect decisions made by firms operating in the specific location. Innovative cluster policies are motivated by the recognition that these market processes cause market failures and are strongly affected by policy implementations. Market failures are related to the various economic effects existing in the clusters. These use to be collective action problems based on lack of collaboration, insufficient levels of investment in innovation activities, and path dependency.

All governments in the EU member nations are active in innovative cluster policies. They organize innovative cluster policies that create benefits for the innovative clusters in terms of effectiveness. The policies cover broad levels from firms to regional economies. At the firm level for interventions, the policies support activities taken by companies and create leverage in the clusters. For interventions at industry level, these avoid many of the distortions related to suppliers in value chains in the clusters. Without the policy implementations, these may often take place. At the regional economy level, the policies support cluster level actions that can be better targeted at the specific issues faced by individual companies in related industries. As a result, the innovative cluster policies can contribute to increasing the effectiveness and reducing unnecessary efforts in the clusters. By implementing these policies, the innovative clusters enable to play important roles in system innovations and smart specializations in any industrial transformation such as the Fourth Industrial Revolution that radically change business models at firms' level and the organization of value chains at industries level. It means that innovative cluster policies are one of the tools for innovative clusters to be able to evolve continuously in the Fourth Industrial Innovation era (Commission 2016).

The EU's innovative cluster policies are carried out by the governments of the member nations based on their local environment and capability, while the EU coordinate and set the emerging industries that strengthen competitiveness and economic growth for the EU as a whole. In 2008, the EU member nations carried out 69 national cluster programs and 88 regional cluster programs. In 2015, 15 EU member nations carried out 16 national cluster programs, and other member nations were in the process of revising their national cluster policies and programs (zu Köcher and Müller 2015).

The main body for carrying out the EU's innovative cluster policy is the European Cluster Observatory, which is the single access point statistical information, analysis, and mapping of clusters in Europe. It aims at being European, national, regional, and local policy makers. Moreover, it plays roles in cluster managers and representatives of SME intermediaries. It was established as an initiative of the Clusters, Social Economy and Entrepreneurship unit of the European Commission's Internal Market, Industry, Entrepreneurship, and SME's Directorate-General. It promotes to develop world class clusters in Europe such as Sophia Antipolis in France, Kista Science City in Sweden in order to strengthen global competitiveness and entrepreneurship in emerging industries. Additionally, it facilitates SME's access to clusters and support globalization of SMEs through clusters. It also focuses on designing smart specialization and cluster strategies that foster roles of innovative cluster policies as part of the Europe Strategy 2020 (https://ec.europa.eu/growth/industry/policy/cluster/observatory/about_en accessed on 08 Oct 2017).

In addition to European Cluster Observatory focusing on regional strength based on sectoral and cross-sectoral cluster mapping, the Smart Specialization Platform and the European Cluster Collaboration Platform are created. The former aims at regional priorities based on research innovation policy priorities, while the latter targets regional partners for fostering European partnerships between cluster organizations. By creating these organizations focusing on different tasks and targets, strategic interregional collaborations become possible that facilitate new cross-sectoral value chains through the innovative clusters. As a result, the total number of strong clusters in Europe increased up to 3034, and 40% of activity in emerging industries were concentrated in 20% of regions in 2016 (Commission 2016).

5.3 Innovative cluster-based economic development and Europe Strategy 2020

Fundamental progress improving economic, social, and environmental conditions requires the investment in an innovation system that needs key factor inputs such as skills and research and development (R & D) funding, an ecosystem of clusters, and other networks all together. In fact, clusters are a significant tool to organize the investments in factor inputs in specific locations that are mostly used effectively. Therefore, cluster effects are mostly regarded as an instrument to improve the efficiency of public intervention in the areas where externalities are the key reason for public policy that can be applied in innovation in high technology (Aghion et al. 2011).

In such a context, cluster-based approaches are the core tool for a new industry policy focusing activities on specific sectors of the economy. These new approaches look for industries that generate the highest potential in a specific location and deploy public policies to enable them more productive in the location that focus mainly on market failures. In Europe, the new industrial policy has gained attractiveness because policy makers experienced positive roles of manufacturing during the Euro crisis (Stiglitz et al. 2013; Warwick 2013; European Commission 2012, 2014).

Cluster-based efforts have already become a natural feature of economic policies in the EU member nations. Particularly, these are visible not only at the regional level, but also at the national level such as innovation and SME support policies. Furthermore, cluster initiatives proved that the highest impact on mobilizing company engagement could be reached if their activities are linked to market demands. Therefore, cluster initiatives can be important instruments to overcome collective actions and fragmented information problems that create high barriers for markets. However, they cannot substitute the markets that companies focus on generating their growth. Therefore, public funding for activities in cluster initiatives is not able to create leverage if companies cannot have any potential market. Accordingly, the government investments in activities can be effective if they are combined with positive externalities such as proper pricing of environmental resources and competition of government R & D funding (Acemoglu et al. 2014; Ketels 2015).

Various cluster programs have provided financial and technical supports to cluster initiatives based on public and private collaborations that focus on strengthening competitiveness of specific regional clusters. As a result, innovative clusters contribute to boosting regional economic growth. The nature of cluster programs varies significantly across Europe that is dependent on individual regional capability and environment. Therefore, all regions do carry out their own cluster programs and developed different ways to integrate their objectives of the new growth path with their cluster programs (Müller et al. 2012).

The Europe 2020 Strategy is based on European policies for global competitiveness. It was launched as an exit strategy from the global financial crisis started in 2008. The vision of the Europe 2020 Strategy is to set a social market economy for Europe in the twenty-first century, and its aims are to transform the EU into a smart, sustainable, and inclusive economy as well as to reinforce the EU's leading role in global governance. Additionally, it focuses on social inclusion and environmental protection. Innovative clusters have played their significant roles in economic development. However, their roles in social inclusion and environmental protection are still limited. It may affect innovative clusters negatively to deal with generating new employment and developing clean technology in the Fourth Industrial Revolution era. Therefore, innovative clusters need to target these areas as well that can contribute to strengthening the EU's leading role as a whole (Ketels 2015).

6 Conclusion remarks

The Fourth Industrial Revolution is approaching to us that is based on hyper automation and hyper connectivity. The key technologies such as AI, IoT, big data, and robot can overcome the gap between physical and cyber systems. The First and Second Industrial Revolutions increased productivity radically in the physical systems, while the Third Industrial Revolution created the cyber system and tired to connect the physical and cyber systems first time although it was not successful in connecting the gap due to the limitation of technological capability. As a result, it could connect humans and humans as well as humans and machines, but not machines and machines. The connectivity between machines and machines can be possible by AI and IoT that is a step forward compared with the Third Industrial Revolution.

All previous industrial revolutions generated high productivities in industries that contributed to generating new employments and high economic growths in the world. As such, the Fourth Industrial Revolution is expected to increase productivity radically and contribute to creating the better world for the human being although it has not proven fully yet and there are still debates about the real impacts of Industry 4.0 on increase in productivity and economic growth. However, in reality, the hyper automation and hyper connectivity enable to build smart factories operated by the key technologies. It means that smart factories will employee least man power due to their new production and process methods. Moreover, it will make possible a new type of a production base located in nearby consumers owing to the new production systems based on the smart production system for high-quality and small customized products, the green production system for sustainable products, and the urban production system for products close to consumers and delivered as quick as possible.

The extreme high capability of the key technologies is also able to change business models in all industrial areas. It will focus on quality and sustainability instead of price competitiveness that requires employees at high skills level. As a result, the trend of the Fourth Industrial Revolution may cause income disparity between employees on the one hand and provide a high level of autonomy for qualified employees on the other hand. It is highly possible that employees of the low and medium skills levels can be replaced by advanced robots using AI in the labor market.

The new trend of the Fourth Industrial Revolution can be applied to innovative clusters that are core areas for technology innovation and new products worldwide. The Fourth Industrial Revolution has already influenced to change production methods in industries and business models in firms within innovative clusters. In order to create the regional economic growths, all actors in the innovative clusters such as firms, academia, and governments cooperate with one another and are integrated deeply. Despite such approaches, innovative clusters face difficult challenges to develop further in the Fourth Industrial Revolution era.

In the EU, all member nations carry out cluster policies for boosting cluster activities focusing on technology innovation and regional economic growth resulted from global competitiveness, while the EU set the guidelines of cluster policy direction. In fact, the innovative cluster strategy is one of the instruments for realizing the EU 2020 Strategy strengthening the global competitiveness that create the sustainable economic development. It also targets social inclusion and environmental sustainability. Innovative clusters in the EU play significant roles in fostering the global competitiveness and generating the further economic growth. However, they have limitations to meet these two additional targets. Overall, it is the difficult challenge in the future how the innovative clusters could contribute to realizing social inclusion and environmental sustainability based on their global competitiveness, while preparing their readiness for the Fourth Industrial Revolution.

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