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How to Respond to the Fourth Industrial Revolution, or the Second Information Technology Revolution? Dynamic New Combinations between Technology, Market, and Society through Open Innovation

MinHwa Lee [1], JinHyo Joseph Yun [2,*], Andreas Pyka [3], DongKyu Won [4], Fumio Kodama [5], Giovanni Schiuma [6], HangSik Park [7], Jeonghwan Jeon [8], KyungBae Park [9], KwangHo Jung [10], Min-Ren Yan [11], SamYoul Lee [12] and Xiaofei Zhao [2]

1 Department of Mater of Intellectual Property, KAIST, Seoul 34142, Korea; minhwalee@kaist.ac.kr
2 Department of Open Innovation, Open Innovation Academy of SOItmC, Convergence Research Center for Future Automotive Technology of DGIST, Daegu 42988, Korea; qiaoke@dgist.ac.kr
3 Department of Innovation Economics, Hohenheim University, Stuttgart 70593, Germany; pyka@uni-hohenheim.de
4 Department of the 4th Industrial Revolution, KISTI, Seoul 02456, Korea; dkwon@kisti.re.kr
5 Department of Innovation Studies, University of Tokyo, Tokyo 113-8657, Japan; kodama-5@ga2.so-net.ne.jp
6 Department of Art Management, University of Baslicata, 105187 Potenza, Italy; giovanni.schiuma@unibas.it
7 Department of Medical Management, Eulji University, Seongnam 13135, Korea; parkhs@eulji.ac.kr
8 Department of Industrial & Systems Engineering, Gyeongsang National University, Gyeongnam 52828, Korea; jhjeon@gnu.ac.kr
9 Department of Business Administration, Sangji University, Wonju 26339, Korea; kbpark@sangji.ac.kr
10 Department of Public Administration, Seoul National University, Seoul 08826, Korea; kwjung77@snu.ac.kr
11 Department of Social Continuing Education, Chinese Culture University, Taipei 86724, Taiwan; mjyen@sce.pccu.edu.tw
12 Department of Public Administration, Yonsei University, Seoul 03722, Korea; samyoul@yonsei.ac.kr
* Correspondence: jhyunl@dgist.ac.kr; Tel.: +82-10-6697-8355

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Abstract: Since Klaus Schwab and the World Economic Forum declared the arrival of the Fourth Industrial Revolution, there has been much discussion about it. However, there is no commonly agreed-upon definition of the Fourth Industrial Revolution. Therefore, we attempted to answer the following four research questions. "What is the definition of the Fourth Industrial Revolution?", "How can we respond to the Fourth Industrial Revolution in terms of institutions?", "How can we respond to the Fourth Industrial Revolution in terms of technology?", "How can we respond to the Fourth Industrial Revolution in terms of firm innovation and start-up strategy?" Brainstorming was conducted by 11 scholars from several countries to answer these four research questions. Therefore, this research is not the end product of four research questions, but a kind of advanced template to answer the four research questions for continuing research.

Keywords: the Fourth Industrial Revolution; new combination; open innovation; dynamics

1. Introduction

Since Klaus Schwab and the World Economic Forum declared the arrival of the Fourth Industrial Revolution, there has been a great deal of discussion about it. The Fourth Industrial Revolution is characterized by a fusion of technologies that blurs the lines between the physical, digital,

and biological spheres [1]. However, there is no commonly agreed-upon definition of the Fourth Industrial Revolution. Therefore, this research aimed to answer the following four research questions.

What is the definition of the Fourth Industrial Revolution?
How can we respond to the Fourth Industrial Revolution in terms of institutions?
How can we respond to the Fourth Industrial Revolution in terms of technology?
How can we respond to the Fourth Industrial Revolution in terms of firm innovation and start-up strategy?

This study used brainstorming methods to answer these four research questions because group participation using brainstorming can facilitate creative thinking [2]. We invited 11 scholars from several countries according to the agreement about the research questions between participants, and we organized brainstorming teams which consisted of two scholars. The eleven participants answered each of the four questions with individual opinions, and each provided references. Therefore, this research does not have separate literature reviews. Furthermore, this brainstorming did not yield final answers to the four research questions; rather, it produced a kind of advanced template to answering them.

The contribution of this research is to let industries and academia develop their own concepts of the Fourth Industrial Revolution, and to respond concretely to these by themselves. If people working in industry or academia develop their own concepts of the Fourth Industrial Revolution following this discussion, they will have opportunities to develop diverse creative business agendas or research topics related to the Fourth Industrial Revolution.

2. How Can We Define the Fourth Industrial Revolution?

2.1. Second IT Revolution

The Fourth Industrial Revolution stirs up various controversies. The starting point of such disputes is the question, "Is there a revolution worth being called the Fourth Industrial Revolution?" The use of new concepts in languages is defined by the definiteness of meaning and order [3]. According to the availability of the Fourth Industrial Revolution and the order of its composition, we can tell whether we can introduce its concept. The triggering of controversies regarding the Fourth Industrial Revolution provides the basis for estimating the definiteness of the meaning and order of the concept.

According to the World Economic Forum, the Fourth Industrial Revolution has been progressing since the start of the 21st century. It is a revolutionary change characterized by the ubiquitous and mobile Internet; cheaper, smaller, and stronger sensors; and artificial and machine learning [1]. The concept of the Fourth Industrial Revolution is defined as the revolutionary change based on recent diverse technologies. This definition does not uniformly describe the technical paradigm.

With the rapid spread of information technology (IT), the development of a society based on the Collaborative Common is defined as the Third Industrial Revolution era or the zero marginal cost society [4,5]. The Third Industrial Revolution focuses on the paradigm shift from the conventional fossil fuel-based society to the renewable energy- or alternative energy-based society. However, the zero marginal cost society concentrates on the absence of the typical increasing marginal cost, which is caused by the spread of the latest IT, such as the Internet of Things and the 3-D printer. Both describe the same phenomenon, but their focuses are different.

Meanwhile, according to Gordon, who analyzed the 100-year American economic revolution, the IT-based revolution after the 1970s is defined as the Third Industrial Revolution. He stated that this age of revolution accelerated inequality despite the technological revolution, and it did not particularly stimulate economic progress except for a short period of growth of about 10 years in the 1990s. Thus, this revolution could not be compared to the Second Industrial Revolution, which was based on combustion engines, from the 1920s to the 1970s [6]. In addition, he stated that the era after the Third Industrial Revolution, in which 21st-century IT spread across all industries, would not

achieve the economic performance of a special technical revolution due to the acceleration of inequality. He pointed out that in the case of the success of the Second Industrial Revolution, the performance of technological innovation spread across all economic societies thanks to the reduction of working hours and the increase in wages, which were triggered by President Roosevelt's New Deal policy, and the performance of a genuine innovation was achieved [6].

According to the Industry 4.0 concept, the Fourth Industrial Revolution dawned through the use of cyber-physical systems (CPSs), the Internet of Things (IOT), and services [7]. Industry 4.0 cannot be defined well, but it includes the following: smart factories, cyber-physical systems, self-organization, new systems in distribution and procurement, new systems in the development of products and services, adaptation to human needs, and corporate social responsibility [8].

Finally, the Fourth Industrial Revolution can be defined as the revolutionary change that occurs when IT proliferates in all industries, that is, the primary, secondary, and tertiary industries. In other words, it is a result of the horizontal expansion of IT. Therefore, the Fourth Industrial Revolution features the creative connection between technology and the market in all industries based on IT, that is, the creative and open combination of technology and the market through open innovation, or growth based on the open business model [9]. However, the characteristics of the Fourth Industrial Revolution can be completely defined only when technical innovation is combined with institutional innovation as in the Second Industrial Revolution.

2.2. Major Technological Disruptions Wigh Digitalization

We are currently facing a period in which a set of major technological disruptions are already visible. (i) The amalgamation (technology fusion [10]) between artificial intelligence and robotics will generate completely new production processes in manufacturing and services with lower resource intensity (basically labor). (ii) Digitalization technologies will massively enter all sectors and will generate new services and a closer interaction with customers. Again, efficiency will be affected positively and many physical products will be displaced by digital products (e.g., newspapers become digital, transport services are no longer required with data transfer, 3D-printing technologies, etc.). (iii) New bio-based materials and energy sources will replace oil-based materials and energy sources [11]. The so-called knowledge-based bioeconomy is required to return to a sustainable development path. Also, (iv) consumers will play an important role in the Fourth Industrial Revolution because, in particular, digitalization technologies will allow for an evolution of a sharing economy (e.g., concerning mobility, food, tools, etc.).

The combined effect will massively change local, regional, national, and international economic structures. New industries will emerge and old ones will disappear [12]. Labor markets will be challenged by large shortages of particular competencies and simultaneously by an abundance of competencies that are no longer required.

2.3. Digital Age with Internet of Things, or Industrial Internet

Various interchangeable labels have been coined and used to describe the innovations of today's new socioeconomic era, such as the Digital Age, the Fourth Industrial Revolution, the Internet of Things/Everything, or the Industrial Internet. In particular, in the last years, the notion of the Fourth Industrial Revolution has been proposed by the World Economic Forum to refer to the drastic and accelerating development of technologies and their impact on society at large.

Our view of the Fourth Industrial Revolution is that it is the development and application of techno-human smart systems capable of improving the efficiency and productivity of production systems as well as supporting a general improvement in the quality of life of individuals and communities [13]. In this view, the key feature of the Fourth Industrial Revolution is the combination and integration of advanced digital-based and intelligent-based machines and platforms with the organic and dynamic nature distinguishing human beings. The Fourth Industrial Revolution refers to the development, deployment, and exploitation of holistic smart systems that integrate technology,

humanity, and biology so that they can deal with old and new soci-economic and environmental challenges, taking into account the specific characteristics of the context at the hand.

Two main drivers of the Fourth Industrial Revolution can be recognized, on the one hand, the development of industries from the pre- to the post- Fordism era, and on the other hand, the development of the internet or 'digital world', i.e., all applications and infrastructures related to the Web. The manifestations of this combination define the technology landscape of the Fourth Industrial Revolution, including the following key dimensions: connectivity; big data; automatization; intelligent agents, robotics; machine learning; artificial intelligence; block chains; sensors; virtuality; 3D printing; and augmented reality. Independent from the adopted ontology and terminology, the Fourth Industrial Revolution represents a paradigm shift with a new wave of innovations characterized by the digitization of business, society, and our lives. These innovations will increasingly transform how organizations and institutions do businesses, operate their productions, affect society, and make their ecological footprint as well as how people live their lives.

2.4. IoT Revolution

We understand that the Fourth Industrial Revolution is essentially equivalent to the evolution of the Internet of Things (IoT) [10]. It is defined as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies. All the items that can be imagined in terms of the Fourth Industrial Revolution have their basis on all the technologies required for manufacturing and implementation of the IoT evolution. In other words, unless all the IoT-related technologies are developed and implemented, all the possibilities mentioned and discussed regarding the Fourth Industrial Revolution cannot be realized.

2.5. Innovation Based on Combinations

The Fourth Industrial Revolution can be recognized as the advancement from simple digitization to innovation based on combinations of technologies enabling companies to innovate their business models, including manufacturing and service engineering. The revolution has the potential to improve economic development and the quality of our life. Furthermore, it will inevitably lead to new job creation, social innovation, and product innovation.

Since the Fourth Industrial Revolution affects business models, it could reshape customer expectations, the quality of products and services, open and collaborative innovation, and the organizational forms to deliver values. Job specifications and professional competencies in various innovative business models should evolve through these developments.

While new technologies and platforms are increasingly enabling citizens to engage with governments, governments are facing pressure to adjust their systems of public engagement and policymaking. New technologies make the redistribution and decentralization of power possible. Technological developments also affect aspects of our individual lives, such as our sense of privacy, consumption patterns, career developments, work and leisure time, social networks, and relationships. The impacts could be bounded by our imagination, while disruptive applications are possible.

2.6. Emergence of Disruptive New Combination

Definition 1. *Emergence of Disruptive New Combinations between Technology and the Market.*

Traditionally, there was a strong connection between a specific technology and a specific market. For example, information technology was usually applied to products in the electronics industry, such as TVs, computers, phones, and so on, while mechanics was applied in the automobile industry. IT was not related to the automobile industry, and mechanics was not related to electronics. In same

sense, technologies were separate, and markets were separate. Information technology and mechanics were somewhat separate, and the electronics and automobile industries were also separate.

Now, such separations are disappearing disruptively and very rapidly. Technologies and markets are combining with each other very fast and in unexpected ways. The disruptive new combinations between technologies and markets are mostly powered by advances in information technology such as artificial intelligence, big data, and so on.

However, involvement of IT is not the most essential part of the innovation. Without IT, such disruptive new recombinations can also arise between technologies and markets. The most important is the 'emergence' of disruptive new combinations between technologies and markets itself. Emergence means that new combinations are voluntary, unexpected, and uncontrollable. We want to expect them, but it is very hard because new combinations are emerging. They are voluntary and unforeseeable in nature; therefore, we cannot predict and control the concrete directions and aspects of the new combinations between technologies and markets.

2.7. Self-Organization and Self-Actualization

"Self-organization of real and virtual worlds for human beings" The self-organization process consists of (1) digital transformation from the real world to the virtual world, (2) optimization by AI based on big data, and (3) analog transformation of optimized estimation from the virtual world to the real world. In this process, step 1 is identical with the third revolution; however, step 3 makes a major difference from the third revolution.

Our definition of Industrial Revolution is 'co-evolution between human desire and technological innovation, as shown in Figure 1.

i.e., first revolution; physiological needs and mechanical technology
second revolution; safety needs and electric technology
third revolution; social needs and information technology
fourth revolution; esteem needs and intelligence technology

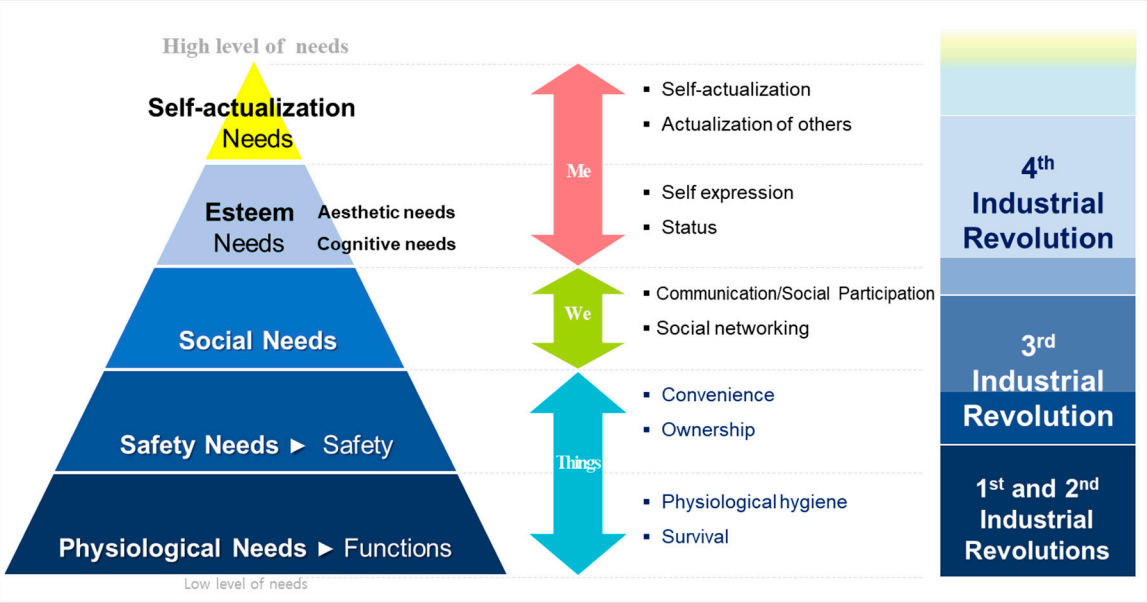

Figure 1. Relation hypothesis between Maslow's hierarchy of needs, and the evolution of industrial revolution.

2.8. Super Disruptive Innovation

We suggest defining the Fourth Industrial Revolution as constituting super-disruptive innovation, which is more powerful than the disruptive innovation claimed by Professor Christensen in 1997. Disruptive innovation is the opposite of sustaining innovation. It occurs to fulfill the needs of new customers with differentiated elements, which is totally different from the previous main market, enabling a new market or niche market to emerge. This revolution is expected to have unexpected effects for human beings, as it goes beyond the market functions of the original disruptive innovation.

This is not the first time that these aspects of the Fourth Industrial Revolution have been noticed. Its various effects were also highlighted by Klaus Schwab at the 2016 Davos Forum. For business, it is expected to provide new forms of manipulation models and innovations, improvements in quality, and so on. However, in society, it might increase inequality and accelerate the collapse of the middle class and polarization of social power. Moreover, it could lead to the reorganization of the roles of government and the global system. Also, at the individual level, it could lead to confusion regarding identity and morality.

2.9. New Industrial Revolution with IOT, Big Data, AI, and Block Chain

The future society brought about by the Fourth Industrial Revolution is expected to experience many changes for the first time. In this regard, it is necessary to develop logic to cope with the emerging social issues related to productivity, jobs, quality of life, as well as social and ethical problems. In general, technological innovation and industry-based revolution are very different. The former is very short-term, whereas the latter is a long-term concept that spans centuries. Of course, depending on the point of view and field of study, the First Industrial Revolution was the start of steam-powered machinery, and the Second Industrial Revolution was the point of factory automation that began with the use of electricity. The common point of the First and Second Industrial Revolutions is that modernization of mankind was achieved by increasing efficiency or productivity of physical space for the use of labor, capital, and land, which are the three elements of existing production. On the other hand, the Third Industrial Revolution can be traced to the use of computers and the networking of computers to expand human activity from existing physical space to cyberspace.

Then, what is the Fourth Industrial Revolution? Technically, it is possible to utilize production factors different from those of the Industrial Revolution, such as the Internet (IoT), big data (new capital), AI, and block chains (trust). It can be defined as an intelligent revolution of industry characterized by continuous short-term innovation with varying levels of speed, scope, depth, and trust. In other words, if the First and Second Industrial Revolutions modernized the physical space, and the Third Industrial Revolution revolutionized modernization in cyberspace, the Fourth Industrial Revolution brought about a fusion of physical space and cyberspace. In particular, the characteristics of the society of the Fourth Industrial Revolution, called the hyper-connected society, are somewhat different from those of the connected society of the IT-based Third Industrial Revolution.

In the traditional information age, information technology has acted as an adhesive between different disciplines or technologies. However, with the introduction of artificial intelligence, the separation of intelligence and recognition and the fusion of virtual space and actual space were achieved. The First and Second Industrial Revolutions constituted a centralized network, and the Third Industrial Revolution constituted a decentralized network in which powerful hubs were dispersed. On the other hand, the Fourth Industrial Revolution constitutes a distributed network wherein all connection points have equal power as shown in Figure 2. In other words, society is becoming more and more closely connected with the interaction of many stakeholders and environmental changes, and the danger is becoming increasingly sociable because there are too many contacts between environment and environment. From a market perspective, the size of the market grows, and the product is a multiproduct society that is personalized.

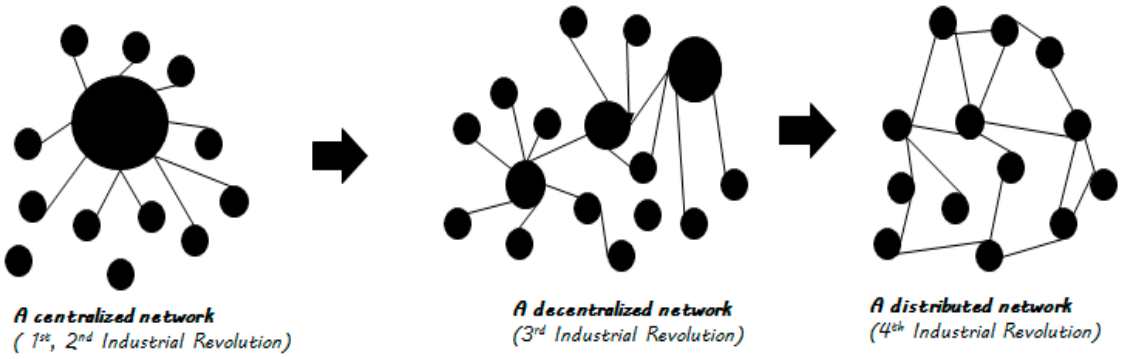

Figure 2. Industrial revolutions and network relationships.

2.10. Manufacturing Innovation 3.0

Numerous definitions of the Fourth Industrial Revolution have been proposed. They include definitions focusing on advanced manufacturing partnership 2.0 (USA), industry 4.0 platform (Germany), revitalization/robotics strategy (Japan), and manufacturing innovation 3.0 (South Korea). These definitions deal with various issues regarding what the Fourth Industrial Revolution is and how to cope these issues [1,14–16]. These definitions consider the impact of the Fourth Industrial Revolution in terms of (1) added value and competitiveness, (2) footprint and new business models, (3) digital start-ups and ecosystems, (4) employee satisfaction at work, as well as (5) sustainability and image. In other words, they focus on (1) the employment ecosystem to create high quality jobs and global competitiveness, (2) revitalization and digitalization of all industries, (3) digitalization of the daily workplace and community activities, and (4) cultural and social transformation through digital interactions among machines, the IoT, and humans. We need a critical evaluation what these transformations and disruptive processes mean for our lives and workplaces. It is necessary to apply a political-economic and sociological approach for a critical redefinition of these revolutionary processes [17].

2.11. The Broad Changes In industries as Well as Society

There have been fierce discussions on the definition of the Fourth Industrial Revolution. Some academics even question whether the Fourth Industrial Revolution is actually occurring, and argue that it may simply be a marketing concept devised by consulting companies. They point out that the term of "the Fourth Industrial Revolution" is mainly used in Korea, unlike other countries. Therefore, it is not a global phenomenon but an isolated case in Korea. However, several studies have countered this criticism. Those who favor the concept of the Fourth Industrial Revolution argue that hyper-connectivity, artificial intelligence, and automation have made disruptive changes in diverse industries. We agree that the Fourth Industrial Revolution is currently progressing, but our definition differs in details. We define it as "the broad changes in industries as well as society that are affected by the disruptive technological changes in artificial intelligence, automation, and hyper-connectivity. It can be called "the Fourth Industrial Revolution" or "the continuation of the ICT revolution." The naming itself is not so important if the naming reflects the severity of the unprecedented disruptive changes human society is experiencing.

3. How Can We Respond to the Fourth Industrial Revolution in Terms of Institutions?

3.1. Improving the Fluidity of Capital and Significantly Strengthening the Entrepreneurial Role of State

The Fourth Industrial Revolution stimulates open connection, that is, open innovation, between technology and the market, while IT spreads across primary, secondary, and tertiary industries, and dynamic new combinations between technology, the market, and society are formed. In other words,

as the Fourth Industrial Revolution is under way, the width and speed of open innovation, and the emergence of new combination business models exponentially increase. Having an institutional system that can accept the wide range and rapid speed of such changes is the key to providing the proper institutional response to the Fourth Industrial Revolution.

First, the fluidity of capital should be improved. Schumpeter focuses on the promotion of new combinations by entrepreneurs and the fluidity of capital that can stimulate such combinations for the success of the Second Industrial Revolution [18]. Alternatively, we need to strengthen the width and depth of crowd funding [19]. With the increase in crowd funding, the activation of entrepreneurs coming from workers, created through major users or customer co-creation rather than capitalists, needs to actually separate capital from capitalists. That will be the key institutional base of the exponential increase in cases of new combinations.

Second, systems should be secured to significantly strengthen the entrepreneurial role of national governments, such as the installation and reinforcement of national investment banks [20] (p. 179). National entrepreneurship recovers the dynamics that have disappeared because of the emergence of individual entrepreneurs, big business-based entrepreneurs, and social closure, and supplements or substitutes entrepreneurship, which is basically not enough in the market [20,21]. It requires the institutionalization of the role and function of the entrepreneurial state, which intensively and directly invests in fields whose social value is high but not immediately shown, such as renewable energy, social innovation, senior citizen welfare, environmental risks, and the resolution of disparities among ages, regions, and classes.

Third, wages need to be increased by significantly reducing working hours and allotting money to social economy. The Second Industrial Revolution was recognized as the completion of the innovation of the internal combustion engine through the institutional advancement of the eight-hour workday and wage increase. In the Fourth Industrial Revolution, productivity will significantly increase due to the innovative new combination between technology and the market. The performance of improved productivity should be sufficiently distributed to workers as well as capitalists to continue the Fourth Industrial Revolution. In addition, a significant increase in the investment of national governments based on taxation in the economic area, where social values exist beyond the market area—such as aging, environment, and renewable energy—is created, that is, the social economy. The rise in big company donation-based investment to additionally create national income will become a new sustainable growth engine by strengthening the distribution of the performance of the Fourth Industrial Innovation.

Fourth, the national taxation structure should be significantly changed. The Fourth Industrial Revolution will inevitably accelerate the concentration on large companies and capital geometrically. The reason is that the exponential centralization of capital through the network economic effect and the platform economic effect is predicted. Thus, nations should make efforts to redistribute income by significantly increasing the corporate tax and the wealth tax by at least 50% to mitigate the inequality that has worsened, revitalize the household consumption expenditure that has decreased, and continuously secure an active economic presence.

Fifth, the institutional system should be significantly strengthened to secure the safety of the Fourth Industrial Revolution, contrasting with the systems for the safety of the internal combustion engine based on the Second Industrial Revolution, such as automobile, airplane, and power grid safety. The Third Industrial Revolution, that is, IT-based vertical revolution, has only institutional security problems, such as privacy. However, the Fourth Industrial Revolution requires similar or much more diverse safety and security systems compared to those of the Second Industrial Revolution. As IT is applied in almost all industries, such as traffic regulation for autonomous cars; the scope and method of information concentration for artificial intelligence; the scope, method, and standard of human activities to respond to intelligent robots; the standard and scope of smart healthcare; and the standards of new risks and safety issues should be established.

3.2. Economic Policy and Innovation Policy Need an Open Design

Technological uncertainty in the transformation caused by the Fourth Industrial Revolution is dominant. Therefore, traditional optimization technologies cannot be applied in a process which has to be characterized as experimental [22]. This holds for economic and firm policy as well as for decisions on the financial markets [23].

Economic policy and innovation policy need an open (future-oriented) design, and instruments focusing on entrepreneurship will become most important [24] in what is called the experimental organized economy.

The Fourth Industrial Revolution is heavily knowledge-based and requires overwhelmingly new competencies. Therefore, education policies are of utmost importance. Education systems need to react quickly on developments in the knowledge space, they need to be redesigned to allow for lifelong learning.

Due to the disruptions, which will become very visible in the labor market, fiscal policy also requires strong reforms. So far, almost all economies tax labor. With massively increasing unemployment due to the increasing employment of robots and artificial intelligence, tax bases are eroded, and this hinders the adaptation of the required (knowledge) infrastructure for the Fourth Industrial Revolution. Therefore, productivity has to become the basis for taxes (e.g., machine taxes, profit taxes, etc.) to avoid further growth of income inequality and social unrest.

Social resilience and creativity could be spurred by the introduction of an unconditional basic income.

3.3. Let Us Make Organisations More Creative and Resilient

The Fourth Industrial Revolution, particularly from an institutional point of view, is bringing opportunities and challenges. The opportunities are related to the possibility of gains in efficiency and productivity that will open new markets and drive economic growth. At the same time, the revolution poses challenges that are related to the possibility of greater inequality, particularly in its potential to disrupt labor markets. The greater benefit is that the Fourth Industrial Revolution has the capacity to enhance the quality of life, letting people work less and better, and have their wants and needs better met by more efficient and productive production systems and digital platforms. Everything that can be digitized and automated will be embedded into intelligent machines and fundamentally, those jobs that are based on codified knowledge or codifiable knowledge will be performed by robots. Thus, all routine-based jobs will disappear, and the roles of individuals within organizations will be increasingly related to auditing activities and, most importantly, innovative and critical thinking.

Taking into account the above, to respond to the Fourth Industrial Revolution from an institutional perspective, it is important to point out that the waves of innovation that the new paradigm will bring entail the development, deployment, and exploitation of technologies, but their initiation and growth are strongly affected by the creative characteristics of organizations. Indeed, at the center of the creation and growth of any technological solution, there are always the aspirations, curiosity, creativity, competence, and passion of the people who have imagined, prototyped, and tested a technology. Institutions need to acknowledge that successful organizations of the Fourth Industrial Revolution will be those that recognize that as much as they have to become more technologically advanced, they need also to recognize the centrality of people in the organizational life and that the most human-based distinguishing factors will increase their importance as key value drivers affecting the creation and delivery of value.

Therefore, the response of institutions has to consider, on the one hand, the support of the adoption and experimentation of new technologies to increase the technological capacity of organizations and, on the other hand, the implementation of human development strategies to make organizations more creative and resilient. For this reason, institutions should adopt policies that can foster two mains strategies: a strategy to govern the techno-digital transformation and a strategy to support leadership and human development capacity. The first is concerned with the adoption and testing of technologies.

The second is focused on six key value drivers: experience, emotions, energy, ethics, environment, and engagement.

3.4. The Continuity in Change

The process of IoT innovation is cumulative in technology and value-additive in business. Its intrinsic implication is the continuity of change. Therefore, the most important capability of institutions is the ability to be flexible, cautious, and alert. At the society level, the mobility of the workforce is critical and an absolute necessity to fully realize the advantages of the Fourth Industrial Revolution. At the individual organization level, the ability to implement the relocation of the workforce is the decisive factor for an organization to survive and grow. In terms of knowledge management, the college and professional education system should be fundamentally reorganized. Interdisciplinary education is not sufficient; rather, a systematic and well-organized knowledge system suitable for the Fourth Industrial Revolution should be newly developed. For its implementation, the existing institutions of training and education of engineers and professional managers may require the comprehensive reorganization of existing institutions into a new system that can accommodate the Fourth Industrial Revolution.

3.5. Dedicated Governmental Organizations and Responsibilities

For many countries, one of the major driving forces for the success of industrial revolution could be referred to the dedicated governmental organizations and responsibilities. Governmental policy is critical to facilitate an eco-innovation system and effective industrial clusters, while the following directions could be a response to the Fourth Industrial Revolution:

- Upgrading industry integrations of research & development, design thinking, service, marketing, and manufacturing for higher added values
- Strengthening the linkages between academia-industry and collaborations for industrial development
- Improving the smart industrial supply chain ecosystem
- Facilitating start-up businesses through various platforms
- Enhancing the development of self-sustainable products and services
- Enhancing the professional competency of critical technologies
- Establishment of government-led standards and common infrastructure for technology development
- Technological and vocational training and talent development systems, including design and business development competency
- Public policy, funding, incubation, accelerator, and tax benefit systems
- Structural policy initiatives and incentives to ensure appropriate resources and employment can be supportive of talent development

Educational institutions should also create mechanisms to reinvestigate the teaching and learning objectives of courses designed in schools and highlight technological changes and their effects on industrial applications and life. Technology can help to facilitate the effectiveness of teaching and learning in many ways, such as e-learning systems, enabling sharing of knowledge, best practices, classroom experiences, and cross-disciplinary learning between diverse geographies.

For technical and vocational training systems, the private sector could help to organize work-based learning for students and promote careers through public campaigns, vocational tracks in education, and investment in technical and vocational training systems.

3.6. Disruptive Emergence and Flexible Focusing

The way to respond to the Fourth Industrial Revolution in job creation, social innovation, and product innovation are disruptive emergence and flexible Focusing. Because it is very hard to predict and control the concrete directions and aspects of the disruptive new combination between

technologies and markets, the best way of responding to the revolution is having and maintaining flexibility in acquiring of necessary capabilities to respond the revolution. A nation can keep its necessary flexibility by widely opening up free grounds for new businesses that started with the beginning of the Fourth Industrial Revolution. Business model promotion and deregulation is the way to keep a nation's flexibility to the revolution. A business model is not technology itself, but it can provide an idea of how to newly connect technologies and markets. The importance of a business model will be getting important and important in the era of the Fourth Industrial Revolution because the basic character of the revolution is new combination between technologies and markets. Without a proper business model, innovations of the Fourth Industrial revolution cannot be fueled and cannot grow further.

If governments are wary of unexpected possible hazards from entirely new businesses and new business models, it would be better for them to allow business models to be developed freely at first, and then to regulate them later based on the actual occurrence of hazards. If governments choose to regulate first and then allow free development of business models later, the possibility of new business models may be lost, and the initiative of new models and innovations will go to other competing countries.

3.7. Transforming Time, Space, and Human Life in the Real World

Necessary actions must be taken for the self-organization of each institution to transform time, space and humans in the real world into Big Data in the virtual world. Then, AI can provide estimations and customizations based on big data. The Fourth Industrial Revolution in technology takes the results out to the real world by analog transformation as shown in Figure 3. In this process, Big Data is the most important asset of initiation, because AI is a commodity. However, we must remember that investigation of human desire is most important for future business.

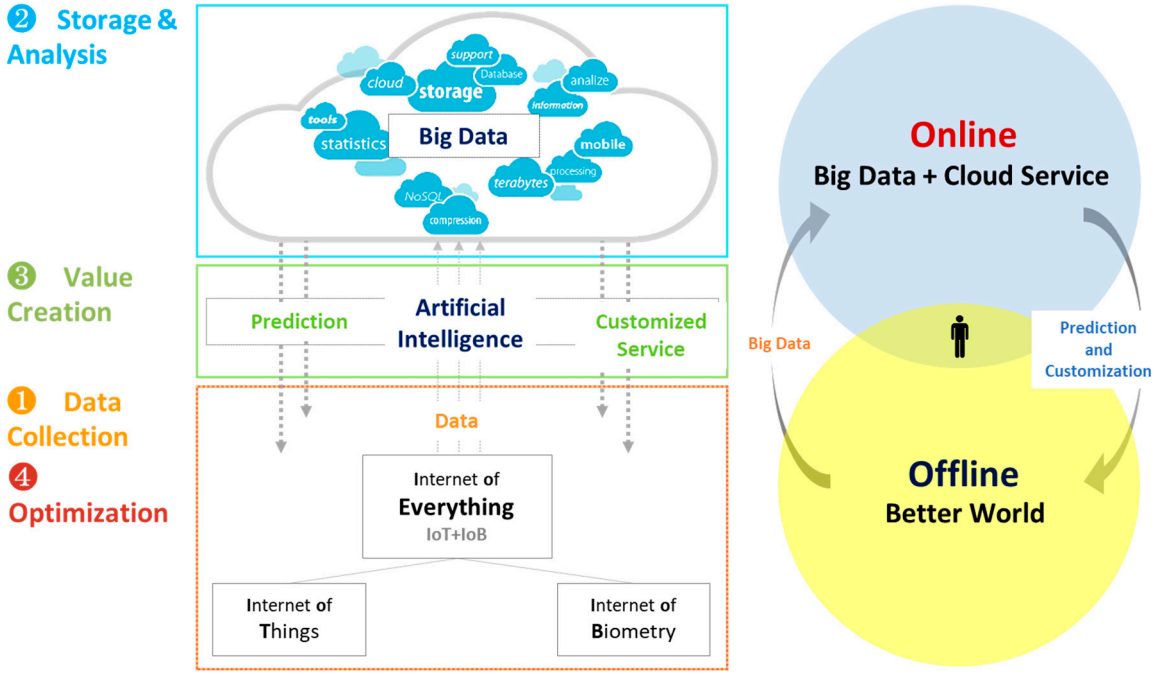

Figure 3. Fourth Industrial Revolution dynamics model.

3.8. New Expansion in Human Labor Resources

In general, business works the best in a free market where no artificial restriction is imposed. Therefore, it is best to reduce regulation and intervention as much as possible to accelerate industrial

competition. The industrial environment changes brought about by the deregulation wave in America's communication and aviation industries [25] is a good example.

Also, new expansion of human labor resources is required. In 20th-century business management, it was believed that the cost in human labor should be reduced. However, this is the story of the past. In the 21st century characterized by globalization, the human labor resource is the key to success, and future management must have a clear understanding of members' strengths, interests, and knowledge [26]. Thus, in the Fourth Industrial Revolution where we will face a plethora of new technologies and products, education must be reformed to improve sensitivity, creativity and communication. In addition, the importance of mutual understanding between scientists and the public will come into focus. The changes of the new technology might cause confusion for individuals in terms of their identity, morality, ethics, and relationships. Therefore, scientists should focus on forming a relationship of trust with the public rather than short term benefits, as the controversies surrounding stem cell research have shown.

3.9. Securing Trust First

Is there a strategy to actively respond to the society in which these new changes are expected?

The first strategy is to initially secure trust. This is also a precondition for securing the permanence of numerous relationships. Also, a strategy for decision making is needed. Insight is more important than predictions because of the high complexity of connections in the Fourth Industrial Revolution. In seeking insight, we seek the essence of the problem. It should be based on understanding the principle and order, focusing on the nature of change rather than speed. However, our society could add confusion to the Fourth Industrial Revolution because of those who want to hide the essence of the problem and those who want to change the essence. Therefore, it is difficult to secure the wisdom of insight only by personal change, and the world must become transparent first. In conclusion, the Fourth Industrial Revolution era should show insight into cooperation with technology as a companion based on trust and transparency, not technology as existing means.

3.10. Government and Civil Society Should Collaborate and Design Together

There are many institutional aspects because the Fourth Industrial Revolution is reshuffling the economic, social and industrial sphere in terms of virtual factories, automated flows, smart machines, and the cyber-production system [27]. These changes have wide-ranging effects, from individual life, to firm-level business strategy and public policy areas [28]. Further we need to consider the institutional implications of these micro- and macro-level challenges. We are facing a new era of real-time Internet-based communication and collaboration among smart devices, smart systems, smart organizations, and humans [29]. Government and civil society should collaborate to design a future sustainable job ecosystem corresponding to the Fourth Industrial Revolution [30]. In addition, digital literacy is becoming increasingly important, and the literacy divide should generate a divide of various outcomes from the Fourth Industrial Revolution.

3.11. Needs to Design a Strategic Plan with Universities and Firms

In Korea, we need to decide whether we will lead the changes or we will be passive recipients of changes. Especially since Korean economy is quite dependent on trade and is relatively competitive in the electronics industry, we are in a good position to lead the changes. Therefore, instead of waiting for real changes to come, the Korean government needs to design a strategic plan with universities and firms. In establishing such a strategy, firms should lead the initiative since it is such an uncharted path that firms facing the disruptive changes should lead the way as pioneers in the unknown gold mines. The government should make adjustments in regulation by working closely with firms. Universities should conduct mid-term and long-term R&D and educate R&D personnel with governmental support.

4. How Can We Respond to the Fourth Industrial Revolution in Terms of Technology?

4.1. Cyber-Physical Systems (CPS)

The technical identity of the Fourth Industrial Revolution is basically cyber-physics. Cyber-physical systems (CPS), which are automated, enable the connection of the operations of physical reality with computing and communication infrastructures [7]. The key features of cyber-physical systems are the following: reactive computation, concurrency, feedback control of the physical world, real-time computation, and safety-critical applications [31].

The technical response to the Fourth Industrial Revolution is totally different from the specific technological catch-up of the existing catch-up economy. In other words, on the premise of the high technical standard of advanced nations, there is no technical project that pursues the standard. The reason is that the technical domain of the Fourth Industrial Revolution is based on the creative combination between technology and the market, and creative recombination projects between technology and the market are rapidly emerging.

The technical project of the Fourth Industrial Revolution is based on the connection and combination between technology, the market, and society, and it should create innovation. For example, there are smart factory systems with a self-organized multiagent systems with big data-based feedback and coordination; smart cities based on an open innovation or open business model platform; autonomous car systems that spread throughout the nation from a specific region; systems of producing, distributing, and using Big Data based on common information; and block chain-based smart finance systems like Bitcoin.

As technical development projects are generally massive technology–market–society projects based on the mutual participation and collaboration of colleges, society, and the government, it is necessary to actively pursue innovation and discuss large technical development projects.

It is urgent to nurture trained individuals for technical development to respond to the Fourth Industrial Revolution, improve educational programs to foster project developers, and actively make research & development (R&D) investment for the education of such developers. As technical development projects are based on the connection between technology, the market, and society, huge investments in education on the integration of technology, the market, and society, as well as basic research on such integration is needed. In addition, the existing administrative, economic, and political education fields need investment in basic research and education for projects on the combination of technology, the market, and society; technology-based market creation and management; and technology-based policy development and implementation capacity improvement.

Furthermore, a new conceptual investment in R&D to find the requirements of the future fundamental technology base of the Fourth Industrial Revolution in science and technology, the market, and society is needed.

4.2. Combinational Technologies

The existing complexity in the development of new technologies will increase even more in the Fourth Industrial Revolution. So-called combinatorial technologies require knowledge transfer and mutual learning in innovation networks [32]. As these innovation networks are continuously changing in the intensity of interactions as well as in their overall architecture, network governance (on a firm-actor and a policy-actor basis) becomes extremely difficult. Complex systems are characterized by their unpredictability and require adaptive management.

Because of the threat of climate change with devastating consequences for the planet, new technologies need to be evaluated according to their impact on the transformation process towards sustainability. Responsible innovation, which increases the participation and transparency of all involved stakeholders, is a promising mechanism to improve the efficacy of innovation policies [33].

4.3. Adopting a Design Thinking Methodology

The Fourth Industrial Revolution is already here, but we are really at the beginning of a radical transformation. We are in an emergent stage where we can start to see the development and application of new technologies. The best approach to respond to the revolution in technology is to adopt a design thinking methodology, focusing in particular on developing and exploiting technologies that are people-centered. Indeed, the key issue for those companies that are already technology masters is to understand what may come next (to look beyond actual technologies and their linear development trajectories) and what areas to explore. The key challenge to govern and respond to the revolution in technology, in our opinion, is related to making technology more human. In other words, the distance between machines and people must be reduced by embedding features that make technologies function as human beings and interact with or support people's activities so they are more attuned to human-based characteristics.

According to the above interpretation of the Fourth Industrial Revolution, we see three fundamental roles of technology that helps to explain how to respond to the technology transformation. In the Fourth Industrial Revolution a technology can fulfil the following roles: (a) Substitute—in which the technology can fully replace people by performing their activities in a more efficient and productive way without compromising the quality or characteristics of the activities' outputs; (b) Integrator—in which the technology is part of people's working activities by extending human capacity and enhancing the precision and quality of human action, but without substituting the human presence; (c) Mediator—in which technology is platform to mediate human life from personal issues to social relationships, i.e., it is the medium through which people interface with other people or with machines and physical objects.

4.4. Practical Knowledge

A firm's capacity for accumulation is its most important technological asset. Therefore, the following virtuous cycle should be established. First, practical knowledge is accumulated systematically in the workplace. Second, the knowledge should be scientifically codified. Third, the documentation of this codified knowledge should be conducted so that good textbooks can be produced. Fourth, training and teaching *methods* should be developed and tested in terms of their effectiveness and validity. Fifth, the new practices established on the foundation of the newly codified knowledge should be tried, and the performance of these trials should be carefully evaluated in an objective way. Then, this cycle should be repeated, starting with the first phase.

4.5. Artificial Intelligence and Robotics

While billions of people are connected by mobile devices and platforms with abundant access to information and knowledge, technological development and applications will be multiplied by emerging technologies, such as artificial intelligence, robotics, the IoT, big data, cloud computing, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, quantum computing and so forth.

Research policies in both the public and private sectors are important to guide technological developments under limited resources. Patent development, knowledge transfer, and the commercialization of technology applications are also critical aspects of the development of technology.

4.6. Not Losing Flexibility Technology

In R&D, flexibility is also a very important factor. Flexibility can be based on a strategy of 'flexible focusing'. Flexible focusing means focusing without losing flexibility. Focusing is the concentration of a firm's resources and efforts to some important needs, such as new business and new product development. Focusing, of course, is necessary for business success because competition is so severe. However, by focusing, a firm can lose its ability to flexibly adapt to unexpected changes and market

developments triggered by the disruptive new combination between technology and market. Hence, the proper strategy in this context is experimentation. A firm's resources should not be invested in or concentrated on only one or two expected R&D targets. Trial-and-error may be the best strategy in the context of unexpected, uncontrollable rapid new combination. It is impossible to know with certainty what will be successful or what will fail. The more trials a firm conducts, the more chances of success a firm will have. Through trial-and-error, a firm can test the possibility of a new business, and, if the test is successful, the firm can expand its investment and concentration into the new business.

Also, the strategy of open innovation by outside acquisition of necessary capabilities is essential. Disruptive new combination occurs very fast and unexpectedly. If a firm only relies on its internal R&D, it may lose the proper time period of entering a newly created market and fail to survive. Flexibility is also necessary in acquiring external capabilities and resources through necessary merger and acquisition (M&A) or strategic alliance. The most important factors here are open thinking of the CEO and cultural openness of the organization.

4.7. Most Technologies Become Commodity or Sharing Resource

Most technologies become commodities or shared resources. The relationships between technologies are more important than each technology itself. We recommend trying to understand the self-organization concept. We suggest the 'AI + 12tech" model for the Fourth Industrial Revolution in technology. It consists of six digital transform and six analog transform technologies together with AI as shown in Figure 4.

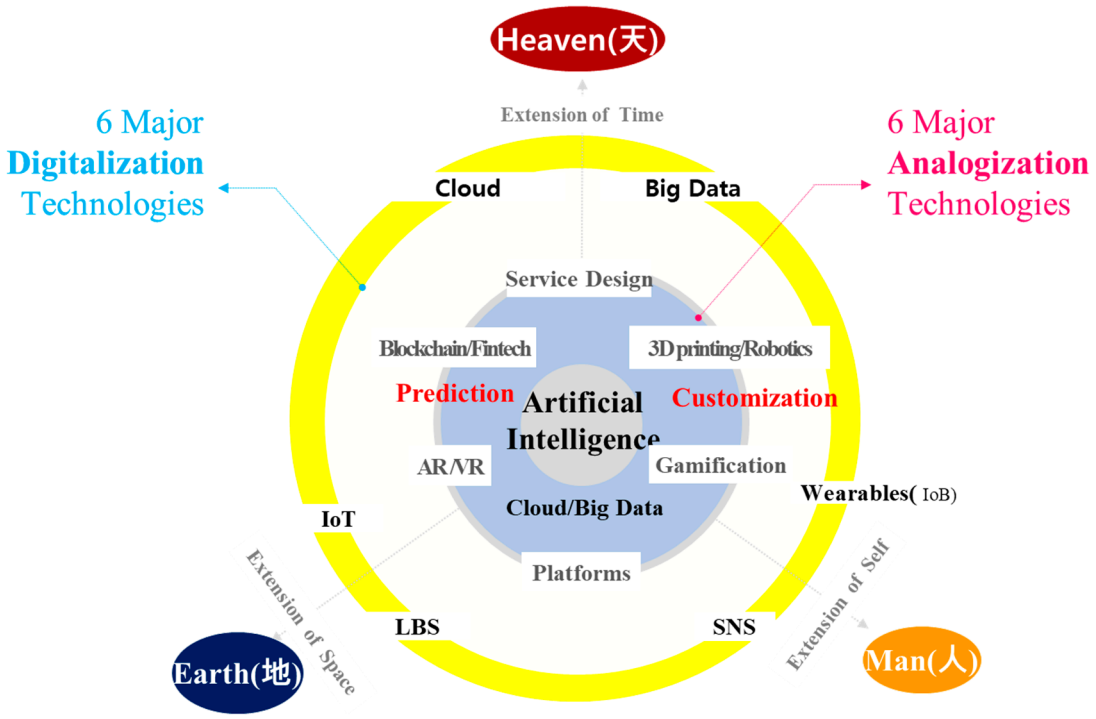

Figure 4. Six digital transform and six analog transform technology models.

4.8. Diminishing the Boundaries among Technologies

The Fourth Industrial Revolution means that the boundaries among the digital, biological, and physics research fields, based on the Third Industrial Revolution, will diminish, making convergence possible. The Davos Forum has announced the selection of 12 hopeful technologies that need a better scientific technology policy in the 2017 Global Risks Report. The two technologies with the highest value are AI and robotics.

Many experts predict that the IoT, robotics, 3D printing, Big Data, and AI will be the top five technologies. Usually, convergence technologies among the ICT-related technologies, physics, and biology create new demands through new products and services, such as smart factories or driverless autonomous cars with smart guidance systems.

Professor Jung Jae-seung of KAIST in Korea proposed two ways to manage the Fourth Industrial Innovation. These have important implications for us. One the one hand, we have to be experts who actively accept new technology. On the other hand, we have to be experts in humanities where only human can do, as the Artificial intelligence is not there yet.

4.9. The Fusion of Virtual Space and Actual Space

In the traditional information age, information technology acted as an adhesive between different disciplines or technologies. However, with the introduction of AI technology, the separation of intelligence and recognition and the fusion of virtual space and actual space have been achieved. Because the size of the virtual space determines the size of the market, it should make people feel the virtual space. AI allows self-realization in virtual space through data patterns like that shown in Figure 5. This actualized space is a kind of platform in the market category.

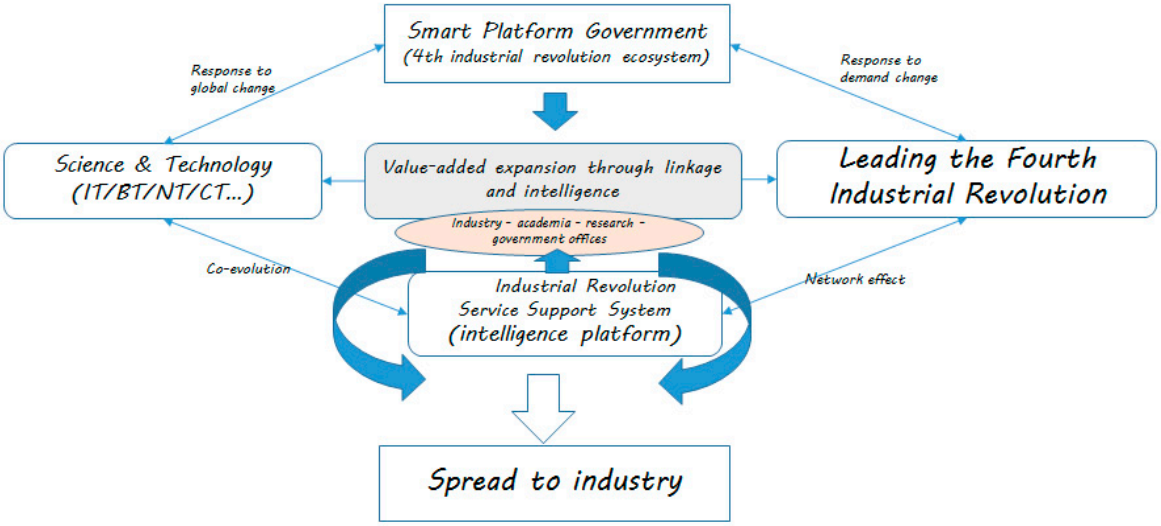

Figure 5. Concept of smart platform government.

The most important feature of AI is the discovery of the characteristics of information through the concept of information abstraction.

Therefore, to realize this effectively, everything needs to be connected to enhance the data collection, analysis, and processing, and the machine will learn by itself with intelligence, while creating a new value of trust. We need a propulsion system that can create a platform. In this sense, open governance as a platform provides the government with a participatory open platform for customers and stakeholders, such as corporations and citizens to provide new services and value-added services. Policies are induced to change the employment structure. As business process changes caused by the Fourth Industrial Revolution create new employment tools, including middle-tech, labor migration policy is needed in the field of human resource development and growth in response to shifts in employment structure.

4.10. Smart Factory, Autonomous Machines, 3-D Printing

It is very uncertain whether we can identify new technologies that the Fourth Industrial Revolution may generate. New technological processes and products include AI, robotics, the IoT, 3-D printing, and autonomous machines. Research papers on the Fourth Industrial Revolution have been published

in various areas, including cyber-physical systems (CPS), IoT), smart factories, Internet of services, smart products, machine-to-machine (M2M), big data, and cloud business [15].

4.11. Adopting Open Innovation Actively

The Korean government and firms need to adopt open innovation actively. Since the expected changes are disruptive in nature, it will be difficult to adequately prepare for the changes to come. To take a path in this uncharted territory, it would be more effective to establish more networks domestically as well as globally. Korean firms need to find a way to utilize global talents in addition to domestic resources. The government needs to admit the limits of the national government in preparing for the coming changes. Universities should make an effort to attract global talents.

The government needs to prepare for the social and economic impact the disruptive changes will bring. Especially when the massive replacement of human labor becomes evident, the government should be ready to address the problem. The scale of the problem will be unprecedented.

5. How Can We Respond to the Fourth Industrial Revolution in Terms of Firm Innovation and Start-Up Strategy?

5.1. New Combination Business Model

The key of the Fourth Industrial Revolution is to continuously connect and combine technology, the market, and society in all industries based on IT. Thus, the core of company innovation or a start-up business is a new combination business model. However, IT itself is not the source of competitiveness for innovation and company business models. How to creatively combine technology and the market, and how well such a combination meets the requirements and expectations of users or consumers are the keys to company innovation. In the First and Second Industrial Revolutions, the technologies themselves were highly important to technical innovation, and business models, including design, were not. However, in the IT-based Third Industrial Revolution, business models were the key of the technical innovation of companies in the IT industry. As the Fourth Industrial Revolution has come, the technical innovation of companies based on business models, including design, has become the dominant innovation paradigm in all industries.

Second, the market innovation in which new combinations between technology and the market are constantly formed requires the continuous occurrence of creative new combinations between technology and society. Companies and entrepreneurs should not ignore this fact [34]. In other words, companies and entrepreneurs should pay attention to the fact that social open innovation will actively be developed to open innovation in the market and that such innovation will actively transform the market to a new growth engine [35]. That is, it is possible for a business model that meets social demands to create social values and market values through a rapid dynamic process [36].

5.2. Established Firms and Start-Ups Need to Cooperate

Established firms and start-ups need to cooperate. Start-ups are definitely in a better position to develop *disruptive technologies*. Established firms might act too slowly because they fear to displace their successful business models of the past and with them, themselves. However, established companies do have strong advantages in the exploitation of new technologies, in scaling-up of production processes as well as in global distribution. A fast and effective implementation of the Fourth Industrial Revolution therefore requires cooperation between mature and new actors.

5.3. New Business Models Exploiting the Digital & Technology-Enabled Platforms

The Fourth Industrial Revolution is ubiquitous and will increasingly transform and reshape operations/production, supply-chain, management, and governance as well as products and services. Whatever could be codified of the organizational life will be put into codes and software and embedded into cybernetics systems that will replace human work activities. At the same time, organizations will

produce and deliver high-tech-intensive products and services. The Fourth Industrial Revolution will bring waves of disruptive innovations, and the magnitude of their effects will be amplified by the combinatorial effect of a wide variety of changes. In the new business age characterized by digitization, mobilization, augmentation, disintermediation and automation, anything that cannot be digitized or automated will become very relevant and valuable. On the one hand, cybernetic systems will have increasing computational capacity and ability to simulate, and on the other hand, the specific and intrinsic human traits will become extremely important to make organizations creative and resilient.

For firms and start-ups there are opportunities on the supply side to create entirely new ways of serving existing needs and significantly disrupting existing industry value chains. Existing firms' business models will be challenged, and new business models exploiting digital & technology-enabled platforms will emerge together with the development of new products and services. Thus, firms and start-ups can focus on how innovations can transform existing industries by increasing efficiency and productivity and lowering the costs and barriers to entrance. At the same time, they can aim to develop completely new products and services based on future technologies capable of generating and eliciting new stakeholders' wants and needs.

In this scenario, what kind of innovation strategies should firms and start-up embrace to prosper in the new business age? In our view, to gain success, they will need to focus on what we label a techno-human strategic approach. In other words, they will need to focus on technology excellence as well as on humanism. First, technological excellence is aimed at adopting, deploying, and developing cyber systems (i.e., advanced technological machines that incorporate the power of digitization and the ability of both AI and robotics). These systems will be able to increase the productivity of organizations, and they will allow the development of new products and services that will enhance the efficiency and pleasure of our personal lives. Already, new technologies have changed how we order a cab, book a flight, buy a product, make a payment, listen to music, watch a film, or play a game. Second, humanism is aimed at ensuring that the distinguishing human characteristics—that are intrinsic to human beings—are deployed and exploited to create and deliver value, and most importantly to meet the deep human needs, wants, and expectations. Human traits, such as intuition, imagination, hope, ethics, and creativity, will play an important role as innovation value drivers. Humanism in the Fourth Industrial Revolution will affect the capacity of organizations to be creative and resilient, and it will define the quality of the customer's experiences generated by organizations and their products.

The techno-human strategic approach has to be integrated with a technology- and creativity-based collaboration strategic approach. The new business age is characterized by the open innovation paradigm, which calls for collaborative innovation. To lever future technologies, established firms and start-ups need to create technology-based collaborations that enable controlled combinations of the technologies underpinning innovations. Such creative collaborations will enable businesses to tap into creativity and knowledge domains that can spur the imaginations of researchers to look beyond technologies towards the future of what might be a new solution.

5.4. Business and Technology Strategy around M&A

Recent investigations on the Japanese experience of IoT evolution, clearly indicate that some kinds of mergers/acquisitions are necessary and effective for the realization of the Fourth Industrial Revolution, both at the level of system integrators and of module suppliers, respectively. However, the conventional wisdom on M&A, in which the priority is placed on short-term profit making, such as the elimination of unprofitable parts of a business, is irrelevant and obsolete. Instead, business and technology strategies around M&A should be studied regarding to realize the effective integration and consolidation of two different business and technology cultures that existed before the M&A. In short, an intensive and broad-based study is necessary about the best ways of conducting M&A to realize the ideal of the Fourth Industrial Revolution.

5.5. Sensible Commercialization

Bottom-up organizational learning and innovation could be important. Sense of commercialization and business development strategy is at the essence of making the real impacts, including the capacity for entrepreneurial thinking, business model innovation, strategic business scenario planning, leadership development, human capital development, financial management, and funding strategy. Entrepreneurial education to facilitating effective firm innovations and start-up strategies is essential and at a leverage point.

Firm innovation and start-up would benefit from financial support and nurturing from the public and private sectors working together. An eco-innovation system is important to sustainably facilitate innovations and start-up through the phases of innovation. Such a system would include grants to support R&D for opportunity and idea generation, angel and crowd funding for intellectual property, challenge funds and tax incentives for seed start-up teams and incubation, venture capital and accelerators to support early-stage growth, government-backed incubators and enablers from the policy and regulatory environment, and equity for the continuous growth.

Human capital matters. The Fourth Industrial Revolution has the potential to empower people and innovations to a far greater degree than in the past, while the creativity, perception, and imagination of human beings at every level of every organization would sustain a core driving force of our world.

5.6. Fair and Mutual Beneficial Cooperation between Big Company and SME or Start-Ups

Small-to-medium enterprises (SME) and start-ups have advantages in capturing new emerging technology possibilities and new market needs. However, they lack the capability of large-scale investment or large-scale R&D to introduce new possibilities and address new needs. Cooperation between big companies and SMEs, including start-ups, is necessary to develop new possibilities of the Fourth Industrial Revolution.

Market experimentation or a trial-and-error strategy can be adopted more by SMEs or start-ups. If such a trial is successful, then a larger company can expand this success. A large company can buy the success of an SME or start-up and share the profits with the SME or start-up through proper M&A and strategic alliances. Such M&A and strategic alliances between large companies and innovative SMEs/start-ups are very common in the US economy. When the US economy is strong, such cooperation is active, but when the economy is wholly dominated and owned by large companies the economy loses its vitality.

Fair and mutual beneficial cooperation between large companies and SMEs or start-ups will improve the possibility of survival in the era of Fourth Industrial Revolution. SMEs and start-ups conduct trials and large companies expand the tested success of SMEs and start-ups. Although this strategy is best at the national economy level, for the strategy be successful, fair and mutual beneficial relationships are required. In the Korean economy, the current lack of fair and mutual beneficial cooperation between large companies and SMEs/start-ups can be great threat to survival in the era of the Fourth Industrial Revolution.

5.7. Convergence of Real and Virtual World

The secret of Unicorn Company is an example of convergence of the real and virtual worlds. The trend of future business is integration of the business value chain called end-to-end (E2E) integration, as shown in Figure 6. Hardware and software are combined to connect products and services (PSS). Thus, unmet human desires can be satisfied through convergence of the real and virtual worlds.

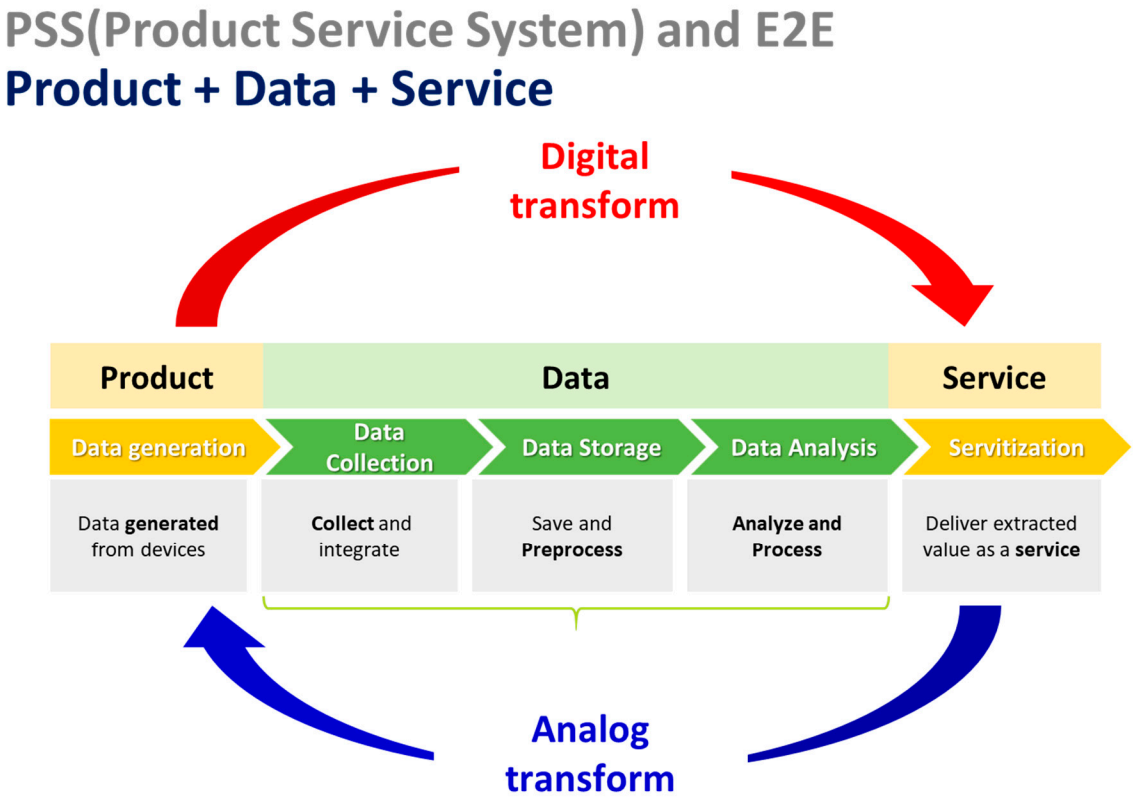

Figure 6. The trend of future business.

5.8. Using External Knowledge Than Internal Knowledge

According to recent research by the Hyundai Research Institute (2016), the results of the growing industries in leading countries led to the conclusion that competitiveness in six industries related to the Fourth Industrial Revolution is increasing in comparison to that of other industries. The Korea Information Society Development Institute (KISDI) analyzed industrial structure changes in 2016. In manufacturing, the application of ICT technology in 3D printing, cloud computing, IoT, and big data is expected. Also, it is reported a changeover to integrated thinking to analyze manufacturing and services as one value chain. Lee and Olson in 2010 claimed that the source of the competitive edge has moved from economy-of-scale to economy-of-scope and economy-of-expertise convergence to economy-of-convergence. Therefore, the digital-based convergence technology should be exploited in a different way from the past. We should disperse the roles between private enterprise and the government. Private enterprise should focus on developing technologies as the disruptive innovations that are needed; the government should focus on supporting basic research and generic technology without profit, which is not easy for the private enterprise to work on [26].

Digital innovation has been identified as having the greatest advantage for securing the competitiveness of a start-up business (Federal Ministry for Economic Affairs and Energy in Germany, 2017). Digital innovation is expected to provide soft power and to be the kernel of power enabling changes in production methods (smartening), changes in trade and distribution (N to N), and convergence. Soft power means the capacity to materialize innovation in business, converging creative ideas with technology, knowledge, and products.

According to an empirical study that was recently conducted, start-ups have been using external knowledge more than internal knowledge to acquire soft power [37]. Although the results are different for each industry, demands from companies and customers are important as external knowledge sources. This highlights the importance of public support for business.

5.9. Deep Data-> Co-Creation-> Open Innovation-> Business Model

To transform existing industries, such as manufacturing, medical, and finance into a customized manufacturing and service industry based on data and intelligent information technology, a platform based on intelligent information technology should be built. In particular, it is necessary to build a value chain system that leads to Deep data-> Cocreation-> Open Innovation-> Business Model. In the case of deep data, we actively support the portion of the cost structure of the Fourth Industrial Revolution and utilize the rest of the system to create the market.

Building deep data that provides high accuracy provides a foundation for promoting convergence between industries and utilization of cloud linkages. In particular, artificial intelligence research should be easily accessible to all fields of science and technology and industry.

To support start-ups and venture start-ups related to the Fourth Industrial Revolution, we should support convergence research of databases among various industries, while actors within the same industry should share the supply chain through governance as a platform as shown in Figure 7. In particular, a deep data distribution market for artificial intelligence development should be established.

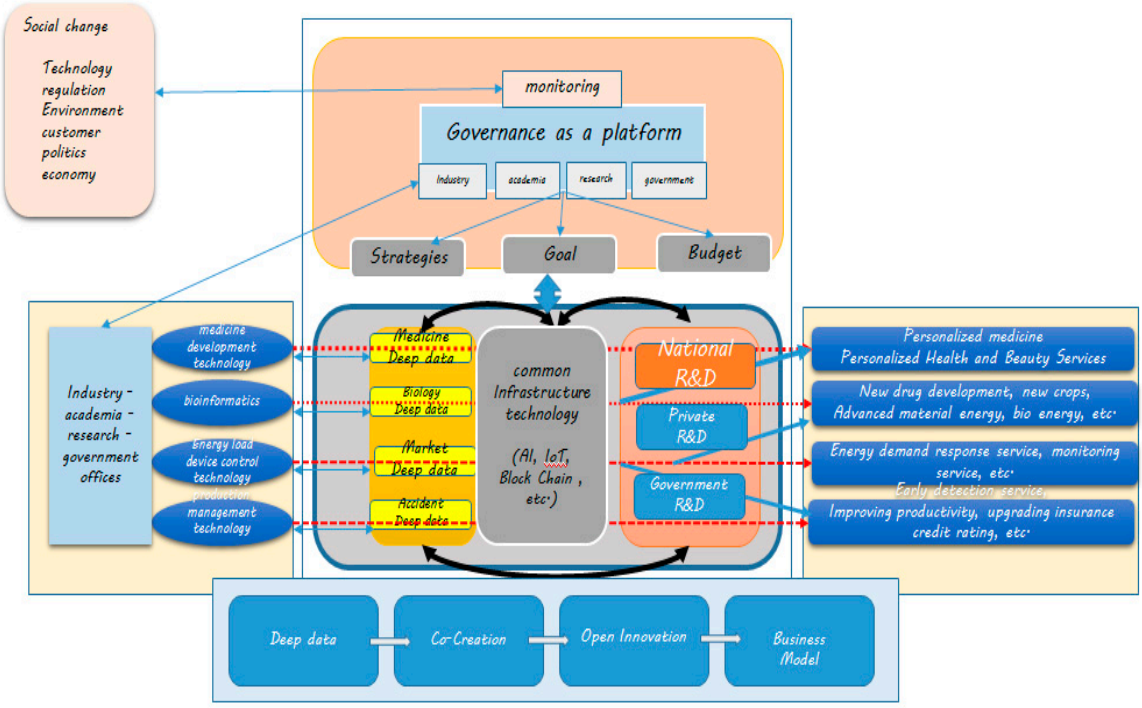

Figure 7. Concept of governance as a platform.

5.10. Increasing the Level of Flexibility

New businesses and start-ups in an era of the Fourth Industrial Revolution should focus on increasing the level of flexibility to the digitalized world and the capacity to generate emerging cyber environments among IOTs, organizations, and individuals. New business opportunities comes from open innovation and social innovation to solve many competing interests and conflicts. More specifically, start-ups should consider the following business trends from the Fourth Industrial Revolution: interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity [37].

5.11. Globalization by Default

The direction for the change will be open innovation and globalization by default. Open innovation is a strategy to create and acquire advanced technologies associated with the fourth generation. Globalization by default is a way to enter the global market. As we observe in the case of KakaoTalk, the Korean market is too small for a company to grow into a global player. Unless a start-up is intended for the global market at its initial start, it would be almost impossible to expand to the top-tier level.

6. Conclusions

6.1. Discussion with Summary

We have four discussion issues here.

First, the definitions of the Fourth Industrial Revolution are as follows; Second IT revolution: Major technological disruptions with digitalization: Digital age with internet of Things or Industrial Internet: IoT revolution: Innovation based on Combinations: Emergence of Disruptive New Combination: Self organization and Self-actualization: Super Disruptive Innovation: New industrial Revolution with IoT, Big Data, AI and Block Chain: Manufacturing Innovation 3.0: The broad Changes in Industries as well as Society.

Second, the ways to respond to the Fourth Industrial Revolution in terms of institutions are the following. The fluidity of capital must be improved, and the entrepreneurial role of the state must be significantly strengthened. Economic policy and innovation policy need an open design. Let us make organizations more creative and resilient. The continuity in change: Dedicated governmental organizations and responsibilities: Disruptive Emergence and Flexible Focusing: Transforming time, space and human in real world: New expansion should be encouraged in human labor resources. Trust between science and the public should be secured first. Government and civil society should collaborate and design together. A strategic plan should be designed through the cooperation of universities and firms.

Third, the ways to respond to the Fourth Industrial Revolution in terms of Technology are the following. Cyber-physical systems (CPS): Combinational technologies: Adopting a design thinking methodology: The practical knowledge: Artificial Intelligence, and Robotics: Not losing flexibility technology: Most technologies become commodity or sharing resource: Diminishing the boundaries among technologies: The fusion of virtual space and actual space: Smart factor, autonomous machines, 3-D printing: Adopting open innovation actively.

Fourth, the ways to respond to the Fourth Industrial Revolution in terms of firm innovation and start-up strategy are the following. Through new combination business models, established firms and start-ups need to cooperate. Such new business models can exploit digital and technology-enabled platforms. Business and technology strategy around the M&A: Sense of commercialization: There should be fair and mutual beneficial cooperation between large companies and SMEs or start-ups. Convergence of real and virtual world: Using external knowledge than internal knowledge: Deep date-> Cocreation-> Open Innovation-> Business Model: Increasing the level of flexibility: Globalization by default.

6.2. Implication

First, the various definitions of the Fourth Industrial Revolution have the common point that the next-generation digital technologies will be the basis of revolutionary change in all industries.

Second, the ways to respond to the Fourth Industrial Revolution in terms of institutions have the common point that the creativity of organizations should be increased.

Third, the ways to respond to the Fourth Industrial Revolution in terms of Technology have the common point that most new combination technologies are important.

Fourth, the way to respond to the Fourth Industrial Revolution in terms of firm innovation and start-ups is the development of creative new business models.

Most of all, the way to effectively address the Fourth Industrial Revolution is the development of dynamic open innovation business models with the expansion of open innovation culture, and the expansion of the feedback loop of an open platform businesses model.

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