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The Fourth Industrial Revolution and the Triple Helix

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Defining and Delineating the Fourth Industrial Revolution

Since the World Economic Forum (WEF) reputed for its global agenda-setting capabilities introduced the term, the Fourth Industrial Revolution, in its 2016 summit in Davos, it has become a new buzzword capturing recent technological breakthroughs heralding social transformations in every corner of socioeconomic life.

In the words of Klaus Schwab, key architect of the forum, the core of the Fourth Industrial Revolution lies in technologies blurring the boundaries of the physical, biological, and digital spheres, as best exemplified by artificial intelligence, virtual/augmented realities, the Internet of Things (IoT), autonomous vehicles, and drones (Schwab 2016).

Table 1: Twelve Emerging Technologies of the Fourth Industrial Revolution (WEF 2017a)

Artificial intelligence and robotics	Development of machines that can substitute for humans, increasingly in tasks associated with thinking, multitasking, and fine motor skills	New computing technologies	New architectures for computing hardware, such as quantum computing, biological computing or neural network processing, as well as innovative expansion of current computing technologies
Virtual and augmented realities	Next step interfaces between humans and computers, involving immersive environments, holographic readouts and digitally produced overlays	3D Printing	Advances in additive manufacturing, using a widening range of materials and methods; innovations include 3D bioprinting of organic tissues
Ubiquitous linked sensors	Also known as the “Internet of Things” (IoT); the use of networked sensors to remotely connect, track, and manage products, systems, and grids	Advanced materials and nanomaterials	Creation of new materials and nanostructure for the development of beneficial material properties, such as thermoelectric efficiency, shape retention and new functionality

Blockchain and distributed ledger	Distributed ledger technology based on cryptographic systems that manage, verify and publicly record transaction data: the basis of "cryptocurrencies"	Geo-engineering	Technological intervention in planetary systems, typically to mitigate effects of climate change by removing carbon dioxide or managing solar radiation
Biotechnologies	Innovations in genetic engineering, sequencing and therapeutics, as well as biological-computational interfaces and synthetic biology	Neuro-technologies	Smart drugs, neuroimaging, and bioelectronic interfaces that allow for reading, communicating, and influencing brain activities
Energy capture, storage, and transmission	Breakthroughs in battery and fuel cell efficiency; renewable energy through solar, wind, and tidal technologies; energy distribution through smart grid	Space technologies	Developments allowing for greater access to and exploration of space, including microsatellites, advanced telescopes, reusable rockets and integrated rocket-jet engines.

While it is apparently straightforward to call an assemblage of these emerging technologies the Fourth Industrial Revolution, there are uncertainties and ambiguities in defining and delineating the scope of this transformation at least in three aspects.

Firstly, technical experts as well as historians of science and technology may well doubt that this is really the "fourth" industrial revolution. According to the WEF's formulation, the current transformation is distinctly the fourth, as the previous industrial revolutions took place based on very different technological systems (mechanical production driven by water and steam power for the first industrial revolution, mass production driven by electrical energy for the second industrial revolution, and automation driven by electronic and IT system). In the views of the advocates of the novelty of the Fourth Industrial Revolution, what is truly new about the fourth one is the integration of cyber-physical-biological system enabled by the above-listed technologies.

Yet, these technologies driving the Fourth Industrial Revolution are critically viewed as the extension of the previous revolution marked by digital technology. In particular, Jeremy Rifkin, the author of *The Third Industrial Revolution* (Rifkin 2011), refutes the WEF's claim by pointing out that the velocity, scope, and systems impact characterizing Schwab's Fourth Industrial Revolution have in fact been the hallmarks of the digital technologies underpinning the Third Industrial Revolution. Both Schwab and he recognize the vast potentials of digital technologies to fundamentally transform the way political, economic and social life is organized around the world, yet the point of disagreement lies, claims Rifkin, is that the Third Industrial Revolution is yet to reach its full potentials and thus too early to be declared to be done (Rifkin 2016).

Another critical view on whether the Fourth Industrial Revolution is indeed the "fourth" is based on the Kondratieff wave theory. Kondratieff waves refer to the long-term fluctuations of 40~60 years beginning with technological innovations and sustained over extended periods of economic prosperity before sudden or prolonged slowdown. One of the widely circulated market trend analyses as shown in Figure 1 posits five such waves with the sixth one characterizing current technological and economic changes (Allianz 2010).

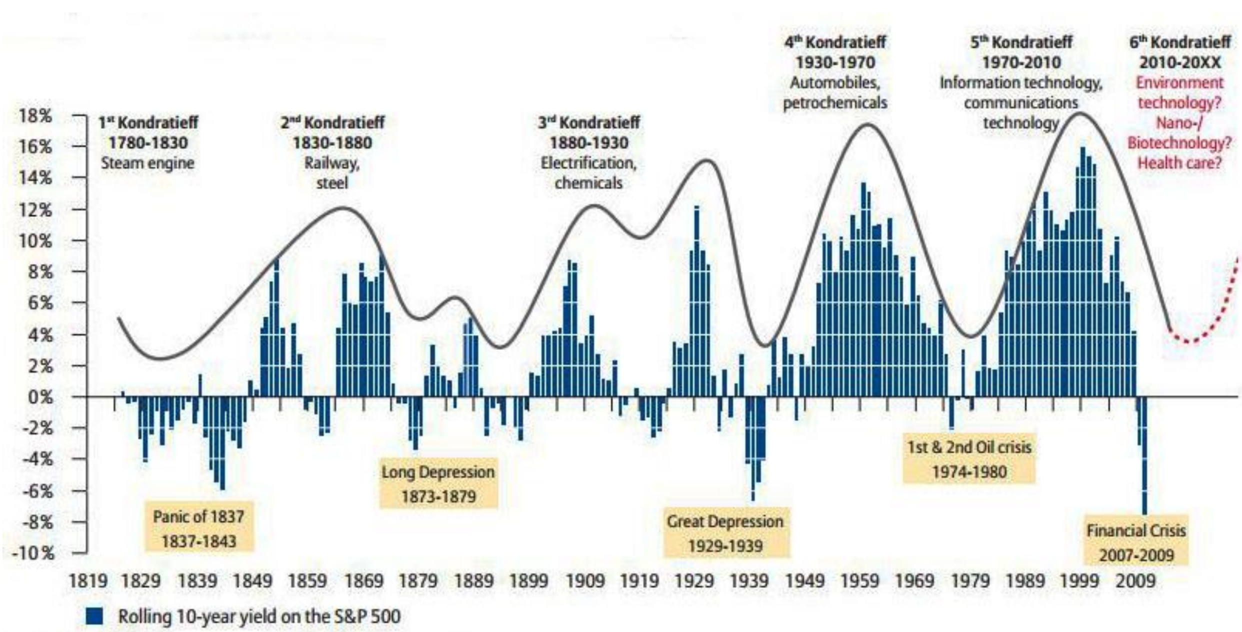

Figure 1: Kondratieff Cycles (Allianz 2010)

Secondly, many observers of the recent technological developments associated with the Fourth Industrial Revolution commonly comment that it is more than the "industrial" transformation. To a large extent, this observation seems trivial, for no previous industrial revolution has been just an "industrial" revolution. Since Arnold Tonybee first coined the term to describe Britain's machine-based economy retrospectively (Tonybee 1884), technological innovations associated with an industrial revolution have always involved social, economic and cultural transformations.

In particular, the question about whether the Fourth Industrial Revolution is more than the "industrial" revolution is linked to the origin of the term, Industry 4.0. Industry 4.0, also called smart industry or smart manufacturing, is a German project launched in 2011 to automate manufacturing production based on digital platforms (GTAI 2014). While it is generally understood to encompass such phenomena as real-time supply chain, data-driven demand prediction, self-optimizing systems, and connected factories, its meaning has been expanded with each company having its own definition. As many features of Industry 4.0 represent the developments linking cyber-physical systems, the Fourth Industrial Revolution in a narrow definition can be interchangeable with Industry 4.0.

Thirdly, there is a question whether the Fourth Industrial Revolution truly "revolutionary." Advocates of the Fourth Industrial Revolution claim that it is so, as the changes it brings about are exponential disrupting almost every industry in every country enabling new capabilities for people and machines and ultimately leading to the transformation of entire systems of production, management and governance.

In the past human history, all real revolutions – whether political or technological – have only come to be called a revolution posthumously. Then, naming the ground-breaking technologies linked to the Fourth Industrial Revolution and their associated changes as a revolution cannot be a mere attempt to describe what is happening now. Rather, it is close to a prescription in the sense of setting a global agenda. And even such effort is viewed to have a dubious effect, as one of the immediate book reviews upon the release of Schwab's book (Thornhill 2016) criticizes the book as an inflight reading that is hard to reach broader audience.

In short, the apparent arrival of the Fourth Industrial Revolution is debated and disputed over the precise definition and scope of its impacts. Yet at least in South Korea it has emerged as a powerful keyword setting the tone of policymaking of the new administration let alone science, technology and innovation (STI) policy.

The Fourth Industrial Revolution in the South Korean Context

Just two months after the 2016 Davos Forum, the AlphaGo match was held in the downtown Seoul, South Korea. Widely televised, the match was proposed by Google DeepMind, the new British start-up company acquired by Google, to challenge humans in the board game of Go. AlphGo, the artificial intelligence (AI) based computer program developed by DeepMind, won over Lee Sedol, world Go champion with the highest rank (9 dan) in a five-game match.

The match result sent a shockwave to people watching the match, for the prediction before the match was predominantly against AlphGo. Since the Go game requires more than simple calculation, many conjectured that even an AI program would not be able to penetrate the strategic logic and insight that could only be accumulated over many years of practice.

The match was all the more impactful in this country, for South Korea has been well recognized as a global IT leader. The government immediately responded with the announcement of the 2 billion dollar R&D project. Named as the National Strategic Project, the initiative primarily targeted the technologies closely linked to the Fourth Industrial Revolution such as AI, self-driving cars, and virtual/augmented realities (VR/AR).

The sudden focus of the national R&D on the Fourth Industrial Revolution technologies became more intensified over the presidential election in the spring of 2017. As revealed in a simple comparison of the frequencies of the search term between the world and South Korea using Google Trends in Figure 2, South Koreans' keen interest in the Fourth Industrial Revolution is very much evident in the continuing rise of searches in the spring of 2017. While the worldwide search shows the peak in the very week of the 2016 Davos Forum subduing in the following weeks, the search of the term in South Korea has risen much more as time went by.

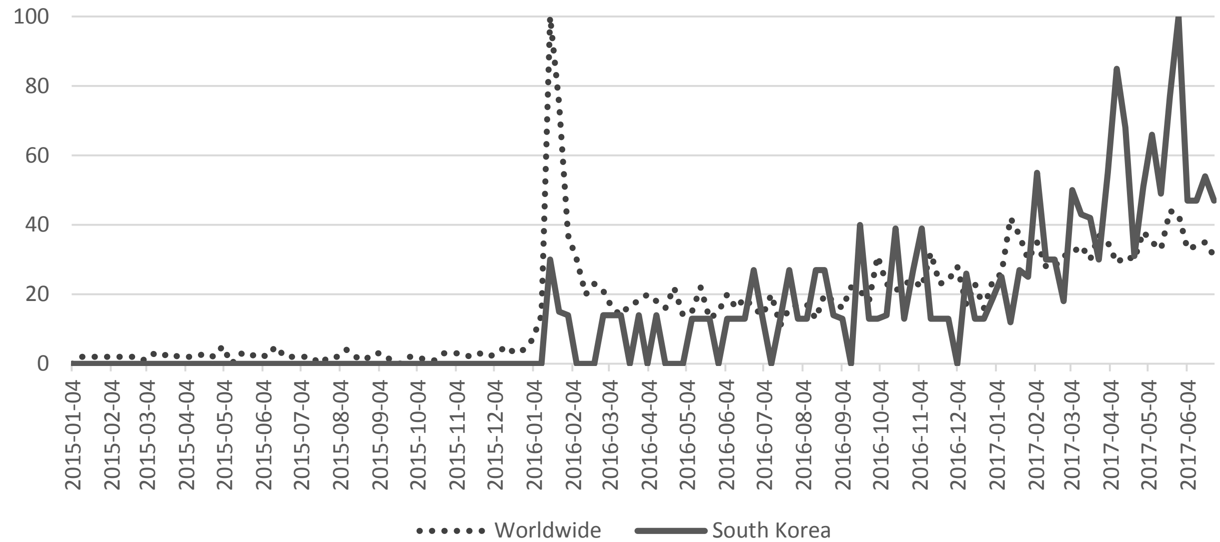

Figure 2: Keyword Search on the Fourth Industrial Revolution (World vs. South Korea)

What was notable in this intense pre-election debate was that it went beyond a simple identification of future strategic areas or fields that the government has to promote for the Fourth Industrial Revolution. The debate touched upon the roles of the government vs. private sector in meeting the system-wide challenges from the Fourth Industrial Revolution as well as various issues of national R&D governance that have long been discussed in the nation's R&D community.

Indeed, when the Korea Federation of S&T Societies, the largest organization encompassing S&T associations in South Korea polled scientists and engineers in June 2017, more than a quarter of the respondents pointed out the reform of education and R&D system as the highest priority in meeting the challenges from the Fourth Industrial Revolution (KOFST 2017). In this survey of 2,350 researchers in various fields of S&T, the responses prioritizing the development of individual technologies driving the Fourth Industrial Revolution such as AI or IoT were in fact fewer than those prioritizing more governance or system-related aspects, i.e., the reform of education and R&D system as shown in Figure 3.

More specifically, the respondents viewed creativity as the most important feature of educational reform (29%), followed by interdisciplinary education (19%) and basic science education (18%). As to R&D reform, they answered the streamlining of redundant legal and institutional measures for S&T (26%) and the abolition of ineffective regulations for technology transfer (25%) as the most urgent tasks in meeting the challenges of the Fourth Industrial Revolution. These survey results naturally lead us to revisit the Triple Helix model in relation to the discourse on governance and policymaking for the Fourth Industrial Revolution.

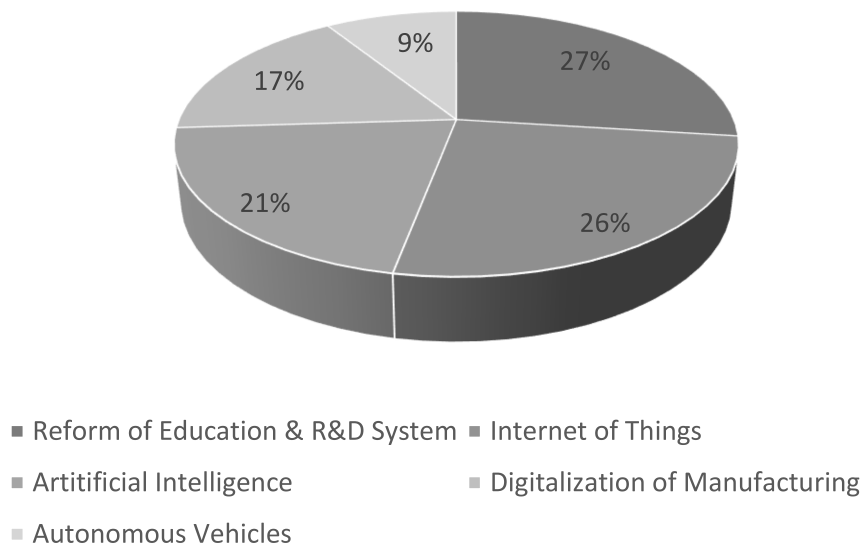

Figure 3: Priority in Promoting the Fourth Industrial Revolution (KOFST 2017)

Challenges of the Fourth Industrial Revolution to the Triple Helix

Amid a plenty of discussions on emerging technologies driving the Fourth Industrial Revolution, the World Economic Forum created an expert group last year to initiate and promote participatory deliberation of the values embedded in the Fourth Industrial Revolution as well as potential risks and hazards of those technologies. Called the *Global Future Council on Technology, Values and Policy*, this group together with other more technology-oriented councils are developing policy approaches and options to shape the future of the Fourth Industrial Revolution. So far four key principles have been laid out through multiple rounds of brainstorming discussions (WEF 2017b).

One is to focus on systems, not technologies. This is effectively a call to avoid technological determinism viewing technology development as natural or inevitable. The second principle is to have technologies empower people, not determine the fate of people unilaterally. The third principle is to think and develop technologies by design, not by default, meaning that much more care and attention needs to be given in order to avoid coming up with technological default blind to various sectors and segments of the society. The last one is to consider value as feature of technology development, not a bug to fix, which is to acknowledge that technologies are inherently value-laden rather than value-neutral.

These principles, together with the aforementioned survey results on the Fourth Industrial Revolution of South Korean researchers, directly call us to re-think the roles of the university, government, and industries that form the Triple Helix of the innovation eco-system and re-imagine their interfaces in the governance of emerging technologies.

First of all, unlike many existing technologies developed with clear performance goals in mind, most technologies underpinning or driving the Fourth Industrial Revolution are being developed without clear end-results in view. This implies that the specific paths of technological development for the Fourth Industrial Revolution are much more likely to depend on how various actors of the innovation eco-system, especially those three main tripartite actors (university-industry-government), perceive the utility and risk of emerging technologies and structure the discussions of alternative futures of those technologies.

Secondly, the increasing demand on creativity and inter-(or trans-) disciplinarity in education and R&D in the face of the Fourth Industrial Revolution suggests that the traditional dual missions of universities – teaching and research – need to be upgraded in the directions of allowing much more room for experiments and learning by doing. In this regard, the rise of design thinking in engineering education is of particular note, as the central pillar of design thinking lies in the ability to identify problems and to remain open-minded to every possibility. As a human-centered approach to innovation to integrate the needs of people and the possibilities of technology, design thinking involves creating choices and shifting through analysis and synthesis that would inevitably necessitate interdisciplinary communication (Brown 2009).

Finally, the indeterminate and uncertain nature of new technologies associated with the Fourth Industrial Revolution would make the Triple Helix institutions and agents all the more important and pertinent, as the interactions within the Triple Helix would go beyond strategizing opportunities from technological innovations. That said, institutions and agents within the Triple Helix networks should pivot around social imaginations of future technologies as well as the sociotechnical governance structure for the of new frontiers opened up with the Fourth Industrial Revolution.

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