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Lessons from Korea's Response to COVID-19: Missing Factors of Sectoral Innovation System

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Abstract This study intends to add a factor to the discussion on the sectoral systems of innovation through Korea's response to the COVID-19 pandemic. The Korean approach is summarized as follows: the first response centers on technology and innovation. These include the development of diagnostic test methods and accurate test kits, first in the world, the use of ICT technology in epidemiological investigations, the technical response in the field, and the competitive edge in the development of medicine and vaccines that were behind the developed countries. The second response is an aggressive effort implemented just after the Chinese announcement, before the domestic outbreak; the third response is the open policy that induces voluntary participation of all subjects and people by opening all information. More important is the leadership at the national level shown in the past Korean experience and most advanced countries. National leadership must be the missing factor.

Keywords Korean response to COVID-19, test kits for coronavirus, medicine for coronavirus, vaccine for coronavirus, sectoral systems of innovation

I. Introduction

On December 30, 2019, the Chinese government announced that unexplained pneumonia had occurred in Wuhan. Then, on January 23, 2020, Wuhan, with a population of over 10 million, was confined. The Chinese government was concerned that the movement of people from the Wuhan region during the Lunar New Year (January 24-26) would infect all of China.

The World Health Organization (WHO) officially named coronavirus as COVID-19 on February 10. Unlike the previous viral outbreaks such as Ebola, MERS (Middle East Respiratory Syndrome), and SARS (Severe Acute Respiratory Syndrome), the COVID-19 virus is highly contagious. It infected the entire world in just a month. Accordingly, on March 11, WHO declares the

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coronavirus a pandemic. Pandemic means a worldwide infection. As of June 6, the cumulative number of infected people in the world reached 6.6 million, and 390,000 people died (WHO Coronavirus Disease (COVID-19) Dashboard). The top five infected countries are the United States (1.9 million), Brazil (620,000), Russia (430,000), the United Kingdom (280,000) and Spain (230,000). Also, the mortality rate per 100,000 people is high in developed countries such as the UK (60.68), Spain (58.07), Sweden (45.56), and the United States (33.36).

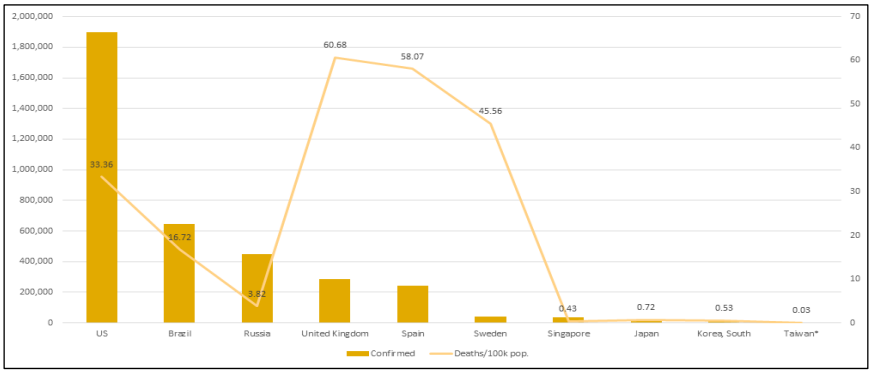

Figure 1 COVID-19 (June 6)
Source: Johns Hopkins University Corona Virus Resource Center

On the other hand, Taiwan and South Korea have very low mortality per 100,000 people, as well as confirmed cases. Taiwan and South Korea are adjacent to China, where COVID-19 started, so there was a possibility that it would spread more rapidly than in other countries, but it was the opposite. As a result, Taiwan and Korea are regarded as representative countries that respond well to COVID-19. In particular, Korea is considered to be the country with a technological response to coronavirus.

In less than 50 days after the announcement of the outbreak of coronavirus, the Wall Street Journal reported on Korea's IT-based epidemiological survey (February 17). On February 20, the 50th day after the outbreak, a Korean company exported coronavirus test kits to a high-end hospital in China. And on March 19, Reuters reports how Korea has overtaken the United States in the testing of coronavirus[1]. On March 25, US President Trump called President Moon Jae-in of South Korea requesting medical equipment[2]. As of March 27,

[1] Terhune, C. et al., Special Report: How Korea trounced U.S. in race to test people for coronavirus, Reuters, March 19, 2020.
[2] Park, Y.B and Kim, S.I., Trump "Please support medical equipments"… President Moon, "Maximum support", Maeil Economy, March 25, 2020.

Korea received requests for quarantine materials, such as test kits, from 117 countries[3]. Korea's response to COVID-19 opens an opportunity to strengthen national competitiveness in the field of healthcare.

In the healthcare industry, the United States, Japan, Germany, and the United Kingdom are recognized to have excellent innovation systems. On the other hand, Korea is assessed to be one or two steps behind these countries. However, the unfolding of COVID-19 raises the following question: Why is Korea leading the world in the diagnosis kit and playing a prominent role in medicines and vaccines for coronavirus?

This study attempts to examine how the innovation system of the Korean healthcare industry is fighting the coronavirus. Specifically, this article analyzes how Korea provided the fastest technological response in the world and how the healthcare sector has evolved in the context of the coronavirus. To this end, section 2 presents the theoretical issue of the sectoral innovation system, the framework of this article; section 3 outlines the overall features of Korea's response; section 4 examines the healthcare technology response; section 5 reviews the system innovation in healthcare; section 6 presents a missing factor underlying the action of the innovation system in the healthcare industry by comparing cases of Korean disease response.

II. Theoretical Review

1. Sectoral Systems of Innovation

Freeman (1987), who first presented the theory of national systems, calls the coupling of the firm and competition, and international competitiveness policy and science and technology policy as the purpose of the national system. Lundvall (1985, 2016) highlights the importance of user-producer interaction in technological innovation under national systems of innovation (NIS). Meanwhile, Nelson (1998) points out that co-evolution between companies and markets is essential for technological innovation.

Meanwhile, Breshi and Maleba (1997), Malerba (2002), and Maleba and Adams (2014) develop the theory of sectoral innovation system (SIS). They explain the difference between sectors, not defined by technology systems alone. The SIS approach is the same as the general emphasis of system innovation theory on the interaction of actors working in any industry. However, the

[3] Park, W.I., Request for anti-coronavirus substances by 117 countries, Seoul Economy, March 27, 2020.

contents of activities are different depending on the technical characteristics of the industry, market attributes, and the practices formed thereby.

Malerba (2002) points out that the industry system consists of actors, knowledge and learning processes, basic technologies and inputs, mechanisms of interactions, processes of competition and selection, and institutions. And he points out that actors in the industry are firms, small organizations or outside consortia, universities, financial institutions, central governments, and local authorities.

However, Etzkowitz and Leydesdorff (2000), and Leydesdorff (2000) argue that the industry-university-government interaction, that is, the Triple Helix model (Etzkowitz, 2008), is more critical in high-tech industries such as medical technology. In the emergence and development of new technologies such as IT and BT, the role of universities increases, and universities, corporate, and governments circularly interact and develop. However, this model exists in various forms. There are cases where the three actors do not meet jointly, as in Korea in the past (Park & Leydesdorff, 2010). Also, in some industries in China, both universities and industries may move within the broad framework of the government (Li & Fang, 2019).

In the high-tech sector, such as healthcare, the interaction between business, university, and the government is undoubtedly essential. However, the government is not a single entity. Still, there are government ministries for healthcare, others for general industries, and still others for the entire national budget. And what is recommended in one area is sometimes proscribed in another ministry. In response to the coronavirus, the healthcare sector wants to ban outside activities. However, the industrial ministries have no choice but to recommend business activities. Therefore, the issue of leadership of the whole government beyond each ministry arises. In Korea, this leadership had exacerbated the healthcare sector and has produced the best results. When there is a conflict among government ministries, or for one purpose, national leadership is essential. This national leadership is a factor that is not discussed in the sectoral innovation system.

2. Analytical Framework and Approach

We analyze Korea's response to the coronavirus through an analytic framework provided by sectoral innovation systems. As discussed earlier, the sectoral innovation system has a unique technological innovation. The central system comprises hospitals and institutions and actors. We describe and analyze innovation in the healthcare sector. In particular, we examine how national leadership works in the systems for innovation.

1. First, to understand the situation, we will review how the coronavirus outbreak unfolds and how Korea responded (Section 3).
2. We also look at diagnostic kits, treatments, and vaccines, which are technical approaches to combat coronavirus, and examines how national leadership worked (Section 4).
3. From the institutional perspective, we look at how the hospitals and hospital systems, which are the leading players, operate (Section 5).
4. Korea's recent responses are, then, compared with those of past epidemics, highlighting how national leadership is essential (Section 6).

III. Overview of Korea's Response to COVID-19

1. Progress Log

South Korea's response started on January 3, after the Lunar New Year holiday, declaring the interest stage in infectious diseases (Level 1). Subsequently, the Korea Centers for Disease Control and Prevention (KCDC) announced on January 13 that it would develop a test method to detect infection within a month. And when the first patient appeared on January 20, Level 2 was declared. Following the lockdown of Wuhan in China on January 22, an expert meeting of the KCDC raised the need to develop test kit.

Table 1 shows the main events of the Korean response to coronavirus. The KCDC got tools ready – infection test methods and test kits – earlier than the outbreak's first case. On January 27, the last day of the Lunar New Year holiday, the biggest holiday in China and Korea, KCDC hosted a closed meeting convening over 20 members of the In-vitro Diagnostic Company Council in the conference room at Seoul Station. The reason why Seoul Station became a meeting place was that many of the company representatives returned to Seoul Station. At this meeting, KCDC disclosed their experimental methods to participating companies and notified them of the emergency approval procedure if they develop test kits. One week later, on February 4, Kogene Biotech was first approved by KCDC, and on February 12, it was the turn of Seegene, and then followed by many companies. This result made Korea the leader in tested cases per 1 million people in the world (March 31)[4].

[4] The Government of the Republic of Korea, Tackling COVID-19 - Health, Quarantine and Economic Measures: Korean Experience, 31 March 2020.

Table 1 Korean History of Coronavirus Response

Events	Date	Response
China's announcement	12.30	
	1.03	Declared Level 1 (Interest)
	1.13	KCDC-Aims to develop test methods within one month
Korea's first case	1.20	Declaration of Level 2 (Attention)-Establishment of Central Disease Control Headquarters
Lockdown of Wuhan	1.22	KCDC, Expert meeting, test kit required
	1.26	Mr. President's order to the head of KCDC
	1.27	KCDC meeting with In-vitro Test Company Council
Four cases	1.28	Declaration of Level 3 (Watch)-Establishment of Central Disaster Management Headquarters (CDCH))
	1.31	RT-PCR test method announced (as of January 30, no diagnostic reagents outside of China)
	2.04	Kogene Biotech, first approval of test kit
	2.05	KCDC, Corona virus isolation success
	2.05	CDCH announces hard penalty for mask hoarding
	2.10	Walking through test, Boramae Hospital
	2.12	Hong Kong and Macau entrants isolated
Large-scale outbreak	2.18	
	2.28	Social distancing begins
	2.24	Declared Level 4 (Serious)
	3.27	Request for test kits from 117 countries
	4.01	All overseas entrants are quarantined 14 days
	5.06	Beginning the distance in daily life: the world's first professional sports start

After the initial outbreak, the government started the campaign for masks and washing hands. Subsequently, after large-scale outbreaks developed, the code for social distancing was implemented (February 28). And the massive spread of viruses around the world, including Europe, has led Korea to quarantine foreign visitors for 14 days since April 1. After the domestic outbreak disappeared, on May 5, professional baseball league resumed, which was the first professional game in the world to be broadcast to 130 countries through

ESPN. Subsequently, on May 6, social distancing was switched to the code of daily life distancing. Korea has repelled the coronavirus without lockdown[5].

2. Government Taskforce

2.1 Response to Infectious Disease by Stage

Korea divides the warning stage for the infectious disease into four levels: level 1, 2, 3, and 4. Level 1 refers to the outbreak in other countries; level 2 refers to domestic cases; level 3 refers to the beginning of the viral spread; level 4 refers to the outbreak of large-scale cases. At Level 1, monitoring is the responsibility of KCDC, but for Level 2, the Central Disease Control Headquarters (CDCH) was established (January 20). At Level 3, the Central Disaster Management Headquarters (CDMH) launched on January 28 to help CDCH, consisting of high-level officials dispatched from various ministries related to quarantine. At level 4, where large-scale outbreaks occur, the Central Disaster & Safety Countermeasure Headquarters (CDSCH) (February 24), a temporary organization with senior officials from each ministry, controls the disaster, not the KCDC.

Table 2 Evolution of government organization against Corona-19

Level	Role	Participants	Content
1	Monitor	KCDC	
2	Patient response	Infection control	
3	Regional response	Infection control + Related central ministries + Local government concerned	
4	National response	Infection control + all ministries + all local governments	Economic Measures

The head of the CDCH is usually the Minister of Public Administration and Security, but the Prime Minister took over to respond to coronavirus. South Korea, which has seen China's lockdown of Wuhan and other regions, has taken this outbreak seriously. What is more characteristic is that on March 19, President Moon convened an emergency economic response meeting attended by both industry and government ministries. The Prime Minister leads the counter-measures against infectious diseases, and the President handles the economic problems. Since then, the organization has been gradually

[5] Campbell, C., South Korea's Health Minister on How His Country Is Beating Coronavirus Without a Lockdown, TIME, April 30.

systematized and has been in operation with the establishment of the Central Economic Countermeasure Headquarters (April 22).

2.2 Basic Principles of Disease Control

Vice Minister of Health and Welfare Kim Kang-lip explained the characteristics of Korea's disease control in a Webinar (May 4) for foreign ambassadors and journalists.

① Unlike other countries, the disease control that allows movement with minimal restrictions; in other words, an open control
② Free treatment without discrimination between domestic and foreign people
③ Cooperation not only with local governments, but also with all groups
④ Active use of ICT technology in providing related information, public relations, management of confirmed and closely contactors, epidemiological investigations, and quarantine.

Director of Central Disaster Management Headquarters, Son (2020), added:

⑤ Public participation based on openness and transparency: The government provides all information to the people to understand the facts and progression, and seek cooperation. It can be described as a so-called democratic response, such as providing information through the webpage, messages through all broadcasting and cell phone text messages (Jo, 2020).
⑥ Active utilization of technologies: A test kit was developed and used, and the Self-Health Check App and Self-Quarantine App were provided to the people under quarantine for the 14days.

2.3 Contents of Open Control

In addition to the government response itself, many guidelines have been provided for people. First, the government controlled the supply of masks and hand sanitizers. The government has enacted and implemented public notices regarding the hoarding of masks and sanitizers from February 5, 2020, and further the export of the supplies.

Second, the government has implemented guidelines for public activities such as social distancing and distancing in daily life according to the open control principle. Social distancing, which took effect from February 28 to May 5, 2020, is enhanced social distance refraining from going out and meetings, and maintain a physical distance of 2 meters or more, and shutdown of every school. Also, action guidelines were implemented in the workplace, such as not using mass spaces, dressing rooms and saunas, and eating in a restaurant without facing each other.

Since then, as the number of cases decreased, the code of distancing in daily life was imposed since May 6. Under this code, schools have opened, level by level, from high school to elementary school, and by grade and by line in a class to keep the distance. The characteristic of this stage is avoiding three situations: massive gathering, close contact, and closeness.

IV. Technological Innovation

In this section, we deal with technological responses to coronavirus and described the three main components: diagnostic kits, antibody drugs, and vaccines. The story about the diagnostic kits was mentioned earlier, so we will only tell the facts and introduce later the hidden reason for the early development – the President's encouragement. As regards medication, we look at the national conference convening the actors led by the President, including ministries, industries, universities, and government research institutes. Next, about vaccines, the emergence of vaccine nationalism will be mentioned, and we will show that, as a consequence, the Korean approach based on technology development is correct.

1. Development of Test Kit

After the Chinese government announcement that unexplained pneumonia had occurred in Wuhan, the first coronavirus test kit was approved in Korea on February 4, about a month later. Many companies have succeeded in developing the kits. Also, since March, requests have been received from all over the world. Since there were too many requests, the Ministry of Foreign Affairs organized a cross-ministry task force for counter-measure supplies for COVID-19 to the world (March 26). At this point, the number of countries that made requests for assistance through diplomatic channels reached 51 countries[6]. Seventy-three test kits received export licenses until May 19, and 57 million were exported to 110 countries (KFDA, May 22).

There are three main types of technical methods used for the coronavirus test kit: molecular diagnostic techniques, antigen diagnostic methods, and antibody diagnostic methods. Korea initially approved the kit based only on RT-PCR (reverse transcription-polymerase chain reaction) method, which is a molecular diagnostic method. RT-PCR is referred to as the real-time polymerase chain reaction, but it is not the same. It is the standard adopted by the WHO and the

[6] Ministry of Foreign Affairs, Cross-Ministry T/F for countermeasure supplies for COVID-19 to the world, Press Release, March 26, 2020.

CDC in the United States. However, Korean companies first created a coronavirus test kit. This method amplifies the virus derived from the patient to determine the presence with a sensitivity of 95% or more. Therefore, the final inspection is conducted at a particular inspection station equipped with analytical equipment and takes an average of about six hours to get the results. There is also a method that enables rapid diagnosis by significantly shortening the amplification process. Reducing the time also has the disadvantage that the accuracy decreases.

The reason why Korea was able to utilize the RT-PCR method, in the beginning, was the introduction of inspection equipment in 2009 to respond to new influenza. Through MERS, a molecular diagnosis market was constituted. There was also a group of experts in testing, such as the Korean Society for Laboratory Testing. In May, there were already 120 test institutions, 30,000 to 40,000 test capabilities per day, and 300,000 kits produced daily (Lee, 2020; May 4). KFDA also approved the kits based on other methods. They approved 50 molecular test kits and 23 immune test kits (KCDC, May 22).

Table 3 Coronavirus diagnosis method

Type	RT-PCR test[1]	Antibody (rapid) test	Antigen (rapid) test
Method	Amplify a specific DNA	Antibody test	Confirm antigen
Characters	Even the Early stage Accuracy 95%↑ Expensive equipment 6 hours± Difficult sample collection	Early-stage impossible 10-20 mins ↓ Accuracy varies	Even the early stage 10-20 mins ↓ Accuracy varies

Note 1. There is also a method that shortens the amplification time. However, accuracy is weak.

The antibody test kit is a method for testing antibodies that occur in an infected person. This method, like women's pregnancy identification kit, has the advantage of being a quick kit that can check the results immediately within 10-20 minutes, and is inexpensive. However, its weakness is that it cannot be used in the early stages of infection when antibodies are not formed. Also, it was avoided because the sensitivity finding positive cases was less than 50%, but recently, a test kit similar or superior to the RT-PCR method was developed.

The antigen assay kit is a method to detect and diagnose a specific protein an infected person has. This kit also has the advantage of being able to quickly produce the results within 10-20 minutes, without the need for an analytical device, and the cost of the test is modest. There are products with a sensitivity of 95% for finding positive patients, and a specificity of 100% for seeing negative patients, even in the early stage of infection. Such a test kit is very efficient for at least the coronavirus.

The inexpensive and accurate test kit has the advantage of being able to respond quickly in the event of a large number of outbreaks. Furthermore, anyone can check himself/herself whether they are infected, so there is no reason for a lockdown, and it is useful in expanding mobility.

2. Medications Development

The current coronavirus is called SARS-CoV-2. There are six known coronaviruses. Some are very similar to the MERS-CoV and SARS-CoV, and the rest are similar to the flu[7]. Therefore, medicines used for viruses in the past have been used as early treatments. Also, many drugs solving similar symptoms are being used as symptomatic treatments, and clinical trials are being conducted to prove their effectiveness. Representative drugs are Chloroquine or Hydroxychloroquine for Malaria and Remdesivir for the Ebola virus.

Dedicated medications are divided mainly into blood therapy and antibody treatments. The blood system is a method of treatment using plasma separated from the blood of a cured patient. This method needs careful separation because it can transfer the disease of the blood supplied. Also, there is a disadvantage of mass production because it is impossible to secure a large amount of blood from cured people. On the other hand, antibody treatment is a method that finds the most suitable antibody from cured patients and uses it as a treatment[8]. Naturally, there are advantages of mass production.

In Korea, Celltrion announced on March 23 that it would secure 300 candidates, and on April 3, it secured 38 super antibodies. On June 1, the results of animal testing were announced as excellent, and in July, phases 1 and 2 will be conducted simultaneously[9]. KCDC is encouraging them by granting a research project on the medication of coronavirus on March 18. They aim the antibody under development for medicine, but are checking whether it can be used for vaccines. GC Green Cross is scheduled for clinical trials of human blood in July.

In particular, a rapid approval system was introduced for coronavirus medicine. The clinical trial review committee reviews first the clinical trials related to Corona 19 and, then, conduct it in a non-face-to-face manner, such as a videoconference. Third, taking into account of the quarantine situation, it is possible to obtain the consent of the clinical trial subjects over the telephone

[7] http://ncov.mohw.go.kr/en/shBoardView.do?brdId=13&brdGubun=131&ncvContSeq=1888

[8] As of June 3, representatives from antibody therapeutics companies include Eli Lilly Consortium, Vir Biotechnology Consortium, Regeneron, Amgen, Sorrento Therapeutics, and Celltrion in Korea. Lilly launched the first antibody treatment for COVID-19 on June 1.

[9] Kim, M.B., Countdown for overcoming Coronavirus… Celltrion, Confirmation of antibody therapeutic efficacy through animal testing, dongA.cpm, June 1, 2020.

(March 27). The government also announced its willingness to cover the cost of clinical trials and secure facilities for animal clinical trials and quick approvals. The US has already introduced a fast track, breakthrough therapy, priority review, and accelerated approval system to shorten the schedule for new drug approvals (Biotechnology Policy Research Center, 2020).

An important point regarding the thesis of this study is the President's willingness to urge the total mobilization of national resources for the development of coronavirus medicines and vaccines. The President visited the Pasteur Institute on April 9 and presided over a joint meeting attended by representatives of government ministries, industry, academia, and research institutes.

The government research institutes later transferred candidates for treatment and vaccines developed in-house to private companies. The Center for Convergent Research of Emerging Virus of the Korea Research Institute of Chemical Technology is a virus research center created by nine national research institutes, and transferred test kits, vaccine candidates, and medicine candidates to different SMEs (June 9)[10].

3. Vaccine

3.1 Technical Characteristics of COVID-19

The SARS-CoV-2 virus has the following characteristics. First, it spreads from the early stages of infection without symptoms. Second, because of this, the propagation speed is fast. Third, the infection rate of the elderly or patients with severe conditions is high, and the risk of death is high. The mortality rate over the age of 80 is 18.3%, over 70, 7.0%, over 60, 1.72%, and there are no deaths under the age of 20s. Fourth, due to this property, the number of cases is rapidly increasing, and there are areas where the number of cases exceeds the availability of treatment beds (Lee, 2020; May 4). That is why a quick diagnosis is required.

In early April, many international leaders, including Dr. Fauci, who is the Director of the US infectious disease institute, think that the coronavirus is a kind of flu, and does not warrant an acute response. The virus is considered to have a small likelihood of reinfection because it generates immune antibodies after treatment. Accordingly, Dr. Fauci evaluated that travel would be free if countries issued immunity certificates (April 16)[11]. However, there are cases

[10] Park, J.Y., KRICT New Virus Research Group, technology transfer of Corona 19 vaccine candidate, Yonhap News, June 9, 2020.

[11] Rodriguez, A., Dr. Fauci says immunity certificates 'possible' after coronavirus pandemic, Here's what that means, USA Today, April 16, 2020.

where immune cells are not produced, and the question of how long the immune cells last has already been raised in March. In the past study of SARS, only a few patients who were completely cured had immune antibodies over the years[12].

In June, Dr. Fauci announces that, even if a corona vaccine is developed, it will not be able to provide long immune protection like other coronaviruses. In some studies, the duration of immunity is 3 to 6 months, mostly less than one year, and the antibody had low resistance and protection (June 2)[13].

WHO classifies the COVID-19 virus into seven types – S, V, L, G, GH, GR, and others – based on amino acid changes due to genetic sequence differences[14]. Fortunately, the core of the coronavirus has not been modified yet. However, if the nucleus is changed, the effectiveness of the vaccine currently being developed is significantly weakened. Even if the ongoing vaccine development is successful, it is not an end to coronavirus.

3.2 Vaccine Development in Korea

- On June 3, the US White House points out that the five companies, Moderna, Pfizer, Johnson & Johnson, AstraZeneca, and Sanofi, are the fastest[15].
- On June 18, WHO predicted that more than 200 vaccine candidates are currently in development, and one or two of them could be developed this year[16].

As previously pointed out, on April 9, the President himself presided over a joint conference on the development of therapeutics and vaccines involving all ministries, industry, academia, and research institutes. In the private sector, Genexine is leading an industry-academia research consortium for vaccine development, including the International Vaccine Research Institute, KAIST, POSTECH, Binex and Genenbio on March 13, ahead of the government. And on June 19, human clinical trials began. Besides, about ten companies, universities, and government research institutes are dealing with the vaccines (Biotechnology Policy Research Center, June 22).

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[12] Cho, S.H., after cured from corona 19, reinfection is unlikely... But maintaining immunity is'unknown', Dong-A Science, March 24, 2020.

[13] Loverace, B. Jr., Dr. Anthony Fauci says there's a chance coronavirus vaccine may not provide immunity for very long, CNBC, June 2, 2020.

[14] Chung, E.K., Head of KCDC, Daily briefing for coronavirus, July 9, 2020.

[15] Weiland, N. and Sanger, D.E., Trump Administration Selects Five Coronavirus Vaccine Candidates as Finalists, June 3, 2020.

[16] Lim, E.J., WHO hope to develop one or two corona19 vaccines later this year, Yonhap News, June 18, 2020.

3.3 Vaccine Nationalism and Evaluation of Korea's Response

An international consortium led by WHO and the European Union and representatives from several countries raises $8 billion to secure vaccines (May 5). They said they would jointly use the vaccine once it was developed. On the other hand, the United States does not participate in this consortium and is taking its securing strategy.

France and other European countries have criticized Sanofi following its announcement that it will first supply the vaccine to the United States, which contributed substantial investment (May 5). Meanwhile, the US also committed $1 billion in vaccine development to AstraZeneca (May 21). The condition is to provide at least 400 million doses to the United States when developed[17]. Moderna and Johnson & Johnson are reported to have the same contract with U.S. government support.

Italy, Germany, France, and the Netherlands signed an Inclusive Vaccine Alliance in early June. It signed a contract to supply 400 million vaccines with multinational pharmaceutical company AstraZeneca, which is developing a COVID-19 vaccine (June 13)[18]. Germany will take a 23% stake in unlisted biotech firm CureVac with 300 million Euros (June 13)[19]. The US Trump government had attempted to buy this company in March.

South Korean President Moon Jae-in was invited as a keynote speaker at the video conferencing of WTO annual meeting. He said vaccines and medicine have a public character. Therefore, Korea will expand support for vulnerable countries (May 18)[20]. It is also in the position to develop its vaccine even if it is relatively late compared to international vaccine manufacturers, against the vaccine nationalism[21].

4. Section Conclusion

Before the occurrence of patients, the President instructed the person in charge of healthcare policy to respond quickly to the virus. This order encouraged the development of diagnostic kits and succeeded. Furthermore, the President headed a meeting where the nation's power actors in the development of

[17] McKeever, V., AstraZeneca receives $1 billion in U.S. funding for Oxford University coronavirus vaccine, CNBC, May 21, 2020.
[18] Kwon, Y.J. "Vaccine Alliance" in four European countries… 400 million doses first, June 15, 2020.
[19] Germany to buy stake in CureVac as world races for Covid-19 vaccine, Reuters, Jun 15.
[20] Seong, Y.C., Moon gives keynote address during teleconference for World Health Assembly, HANKYOREH, May 13, 2020.
[21] Moon, T.H., Development of vaccine and treatment for Corona19 will be supported until to see the result, Medifarms, June 3, 2020.

treatments and vaccines were gathered. As a result, antibody drugs are now at the forefront in the world, and vaccines are being developed in-house, lagging behind the world's best. It has a technological foundation to cope with vaccine nationalism.

V. Health System Innovation

1. Basis of the Healthcare System

Korea ranks second in the number of hospital beds, with 12.3 beds per 1,000 people, following Japan (13.1). However, most of these beds were in private hospitals, and the proportion of public hospitals is tiny. Also, there were 1,027 negative pressure beds at the end of 2019.

Before MERS in 2015, there were 19 hospitals and 119 negative pressure beds. And there was no hospital specializing in infectious diseases. However, in 2017, the National Medical Center was designated as a central contagious disease hospital, and another infectious disease hospital was established in Honam. Also, two hospitals specializing in infectious diseases were set to Busan and Cheonan in early June when the coronavirus was progressing. Their main task is to diagnose patients with contagious diseases in the region and to provide education and training for experts in responding to infectious diseases in public and private medical institutions. In an infectious disease crisis, it also performs functions such as treatment for severe patients in the region and support for the classification of severity.

What is unusual is that Korea’s medical insurance system employs a nationwide mandatory enrollment system so that anyone can receive treatment for a small fee. However, the cost of diagnosis and treatment related to coronavirus was free, regardless of foreign or Korean. As a result, rumors circulated in countries that if we go to Korea, we will receive free treatment and live. However, the test fee ranging from the US $ 115 to 185 was paid if not recommended by a doctor.

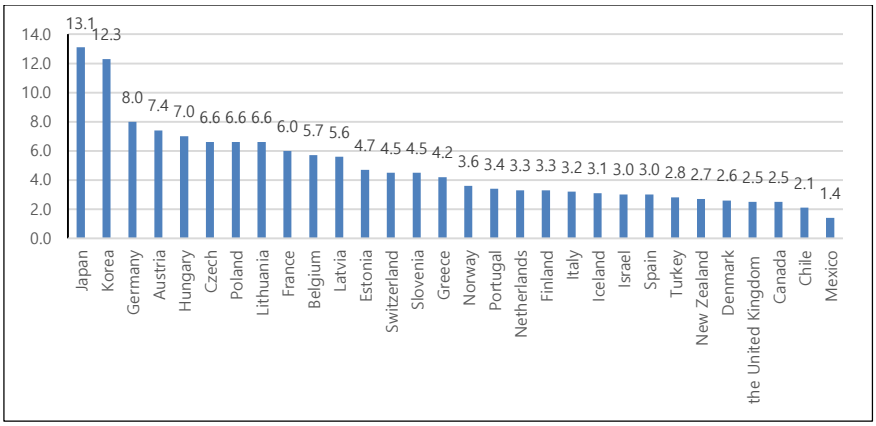

Figure 2 OECD (2020), Healthcare Resources

Note: Number of hospital beds per 1,000 people (2017)

2. Health System Innovation

2.1 Infection Control

Korea's infection control was divided into six areas: controlling infection, responding to confirmed patients, investigating infected patients, treating patients, providing free patient treatment, and mobilizing resources (Lee, 2020). In terms of sectoral measures, it is not much different from other countries. However, Korea is characterized by the fact that infection control is open to the public. Therefore, quarantine of immigrants and thorough epidemiological investigations and inspections of infected people was inevitable.

Although slight differences exist depending on the time of the proceeding, overseas immigrants must submit a quarantine card at the same time as they enter the country and will be diagnosed. In this process, the confirmed is sent directly to the treatment center, and the person with a negative test result is given a Self-Isolation App and a Self-Diagnosis App for 14 days. Self-Isolation App is necessary during self-isolation. This app manages those who breach the terms of their quarantine. The Self-Diagnosis App is an app that automatically sends the information to the designated quarantine officer if the quarantined person enters the body temperature and condition every day. This app checks the health of the person.

The epidemiological investigation was conducted in four stages, as shown in Figure 3. The process is as follows.

1. Investigation: Conduct interviews with patients, primary care physicians, and families
2. Risk assessment: Identification of visits, medical records, cell phone records, credit card transactions, visitor CCTV

3. Contact classification: Close contact, daily contact
4. Contact management: Movement restriction, monitoring

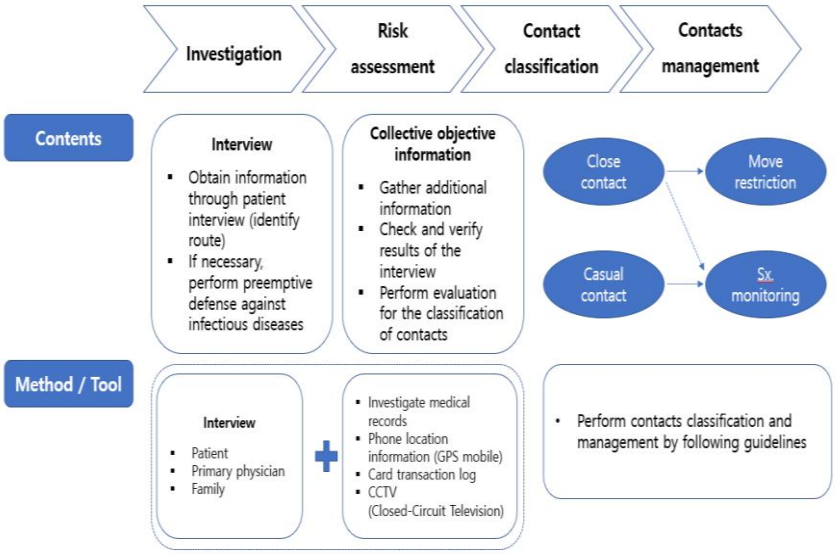

Figure 3 Contact tracing strategy: stepwise approach

Source: Lee (2020)

The most challenging stage is gathering information, but the survey was conducted in about 10 minutes as IT technology is used to connect various organizations. This procedure is very useful in speed and accuracy. The IT technology used for epidemiological investigation, however, is concerned about personal information infringement and human rights, so personal information is excluded and transparency of use is maintained.

2.2 Infection Inspection and Field Innovation

One of the characteristics of Korea's response to coronavirus is that it actively introduced innovative ideas in the field. The innovations include the following.

- Feb 28 Approval of drive-through screening station started by Incheon Medical Center
- Feb 10 Walk-through screening station (5 mins for one person) by Boramae Hospital
- Mar 02 Living Treatment Centers for mild patients by the Korean Medical Association
- Mar 10 Negative Pressure Diagnosis Booth by Busan Jung-gu Health Center

- Mar 25 Incheon Airport, 40 Walking Through Inspection Centers
- Jun 17 Sample collection booth without protective clothing and masks, first in Gwangju
- Jun 18 Simple emergency ventilator with increased mobility and low price

Since March, just after the coronavirus, the US White House's OSTP-sponsored multilateral conference for Corona 19 has been held regularly by science and technology ministers or advisors from 18 countries, including Korea. During this process, it was revealed that Korea is undergoing R&D without a lockdown, and OSTP requests that Korea introduces the R&D Guidelines for COVID-19 (Ministry of Science and ICT, February 27). The Korean government translated and distributed them in 17 languages[22]. The guidelines include measures such as the extension of the research period, change of plans, online use, and encouraging enforcement of anti-infection expenses (masks, disinfectants) within 5% of the research budget.

2.3 Hospitals and Beds

On February 18, the 31st patient was identified at Daegu, who belonged to a religious group called Sincheonji, and a large number of confirmed infections occurred in this religious group. Table 4 shows that, on February 19, 13 out of 15 outbreaks nationwide occurred in the Daegu-Gyeongbuk region, and 11 were related to the same religious group. After about two months, 6,832 patients were diagnosed in Daegu alone. Therefore, the hospital system collapsed, given the lack of medical personnel, lack of hospital rooms, and lack of medical supplies in this area.

The confirmed cases were distributed to hospitals nationwide where there are negative pressure rooms, and some confirmed cases were treated in living treatment centers. Corona patients are classified into four stages: mild, moderate, severe, and very severe. Minor patients are quarantined in a living treatment center, and the rest are hospitalized in a formal hospital. The Korean Medical Association initiated the living treatment center. On March 2-8, four living treatment centers had been opened for 1,095 people. The education and training centers of governments, universities, and large corporations were targeted, and each center was dispatched and managed by university hospitals and large hospitals. Since then, in the case of facilities owned by private companies, the Prime Minister expanded the living treatment centers nationwide by asking the representatives of the companies to lend them facilities[23]. Hospitals, treatment

[22] Choi, M.J., K-infection control supprised by the White House…Worldwide rushing request for Korean R&D Guidelines, June 21, 2020.

[23] Shin, E.B., Call the companies and say, "Beds for corona 19, Please" Prime Minister Segyun Jung's quiet worlk in Daegu, Hankook Ilbo, March 14, 2020.

centers, and medical personnel involved in the treatment and prevention of coronavirus were compensated separately.

Table 4 Cases in Daegu-Kyungbuk Province in February

	Test		Cases		
	New	Accumulation	New	Daegu-Gyungbuk	Accumulation
February 18		9,234		1	31
19	1,131	10,365	15	13	46
20	1,714	12,079	36	35	82
21	2,381	14,460	74	62	156
23(Sun)	8,173	22,633	207	155	763

Sources: KCDC Daily Briefing.

The Central Disaster Management Headquarters announces the COVID-19 Community Infection Response Strategy (February 21). This guidance includes measures to prevent the outbreak in each local government. A distinctive feature is the national safe hospital, which is a hospital that is open only to non-corona patients, so that non-corona patients can use it safely. Several hospitals were designated as such by region.

2.4 Medical Personnel

The shortage of medical personnel was either supported by the military or supplemented across the country. Doctors from military hospitals, doctors who are expected to complete a specialty and become new military officers, and candidates for nursing officers who will soon graduate from the nursing academy have been mobilized into the area. President Moon encouraged them by attending the graduation ceremony (April 2) of nursing officers, and immediately dispatched them to the Daegu-Gyeongbuk region, where the medical shortage was severe.

2.5 ICT and Information Disclosure

In this crisis, Korea is disclosing information to the extent that it does not harm personal information through information and communication means or reporting. Just after the outbreak, KCDC opens a coronavirus webpage that can be referred by medical staff and the general public, it conducted comprehensive daily briefings, and all broadcasters and mobile phone operators transmitted news informing the public about the outbreak and prevention measures. Besides the efforts of the central government, local governments have been provided with mobile apps such as Seoul's "Corona Guidelines" and "Corona 19 Gyeongnam".

In the private sector, various mobile phone apps were created and distributed free of charge, including information on the status of confirmed patients, patient visits, proximity to patient visits up to 100 meters, corona common sense, severity classification, and infection check. The number of such apps for the general public reached 18, but the number gradually decreased with better apps. In February, there were Corona Map and Corona Now created by college students. In March, Corona Doctor, also designed by students, and My Neighbor Vaccine and Corona Self-Diagnosis were added.

3. Section Conclusion

Innovation in healthcare systems has taken place in various fields. However, here too, the authors suggest that attention should be paid to the leadership by the nation's top leaders. First, in Korea, healthcare professionals are allowed to implement measures according to their expertise. Second, however, direct support for the deficiency of the sector was provided, such as securing Living Treatment Center for beds and mobilizing military medical personnel, which is impossible in the healthcare field alone. Third, the mobilization of all government ministries, such as inspection of confirmed cases and compulsory control through the mobilization of administrative personnel, without impinging on the sector experts' decision, should be discussed. The importance of these seemingly apparent measures is presented in the next section.

VI. Discussion – Missing Factor in the SIS discussion

To highlight the characteristics of Korea's response to coronavirus, we examine the response to Korea's past infectious diseases.

1. Response to Foot-and-Mouth Disease in 2010/11

Foot-and-mouth disease (FMD) is an epidemic that occurs in cows and pigs with cracked hooves. FMD in Korea occurred in 2000, 2002, 2010-2011, and every year since 2014. Among them, the outbreak of 2010-2011 was the largest, and the damage was most significant (Ministry of Agriculture, Food and Rural Affairs, Korea Rural Economic Institute, 2019). The 2010/2011 FMD outbreak necessitated about 4,500 burial sites for 3.5 million animal carcasses across the country. As a result, almost all areas near the countryside were blocked entirely, and the whole country suffered great confusion over beef and pork surges. Due to the occurrence of 126 days, the government's expense amounted to around US$ 2.9 billion (Go & Seol, 2013).

The counter-measures consisted mostly of killing and burying, which differed significantly from other countries. “First, it impacted 71.1 kilometers per day of road, requiring a quick response. Second, it was impossible to move to other areas without passing through densely populated areas when moving for the killing of infected and nearby livestock. Even the movement to other places in the same area had to pass through the densely populated areas. Third, most livestock burial sites exist right next to livestock farms because there were no landowners to provide livestock burial sites. Fourth, there were many burial sites having tens of thousands of carcasses (Ko & Seol, 2013).”

The problem was mainly related to the burial process and the response after the burial than the infection itself. The agricultural ministry in charge of the promotion of the livestock industry said that there was no problem with burial. So even if tens of thousands of animals were buried in one place, there was little follow-up management unless leachate was severely released. Local governments also wanted to expedite the process because there were no experts to deal with it. Lee (2013) assesses that the response had been made from an industrial perspective rather than an environmental perspective.

However, Ko et al. (2017) point out that Korea’s response to FMD at the time was not a scientific approach, but a political one. Lee Myung-bak, President of the infection at the time, visited the Central Disaster and Safety Countermeasure Headquarters on February 11, 2011, and in full swing, ordered a quick end. Because there was a parliamentary election in April, however, livestock infections could not disappear at the speed that the President wanted. As a result, local governments in charge of managing the outbreak site also responded with rapid burial, and all scattered outbreaks and follow-up management of burial sites in each region were handled behind closed. All issues that could create public anxiety or antagonize the government were dealt with behind closed doors. And this tradition of secrecy continued into the next presidency.

2. MERS Response in 2015

The global infectious diseases of humans in the 2000s were SARS (2003), H1N1 (2009), avian influenza (H7N9, 2013), Ebola virus (2014), MERS (2015), and Zika virus (2016), but Korea suffered greatly from swine flu (2009) and MERS (2015).

The new influenza virus of 2009 was reported in the United States in April 2009, and occurred in more than 200 countries around the world, ending in August 2010, killing 18,500 people. In Korea, 15,160 people were infected, and 260 died (KCDC Infectious Disease Portal).

Meanwhile, in 2015, MERS caused 186 confirmed cases and 38 deaths by the end of July 2015, resulting in a high fatality rate of 20.4 percent, resulting in

economic losses amounting to about US$ 2 billion[24]. The problem is that only some Middle Eastern countries and Korea suffered from such infections, which led to the refusal of Koreans from other countries to enter the country. The prestige of the nation had been significantly damaged.

Reflections on this suggested 1) improvements to the epidemiological investigation system, 2) enlargement of epidemiological investigators, 3) arrangement of isolation methods by severity, and 4) establishment of infectious disease information systems, and maintenance of infectious disease control systems throughout the country (MERS White Paper, 2016).

Strictly speaking, these suggestions point to the fact that the Korean government failed to respond to MERS. A poll conducted in June 2015, during which MERS was in full swing, showed that the President's approval rating plummeted[25]. The main reason was the failure to respond to MERS.

3. Coronavirus Response in 2020

However, it is not up to the government ministry in each sector to manage the system to allocate resources to deal with the deficiencies in the healthcare system in times of crisis, if the crisis affects the whole country. In the 2010/11 crisis, the President wanted only a quick solution by any means, and as a result, there was no further innovation due to the prevalence of secrecy. The 2015 response showed a similar pattern. Innovation efforts in the system are significant, but leadership across the country that supports the innovation system is critical to the system.

January 27 was the last day of the Lunar New Year Holiday when many people were moving, and transportation paralyzed. Nevertheless, the KCDC held a meeting with about 20 companies. The meeting is based on the President's call to the head of the KCDC during the Lunar New Year holiday on the 26th, a day earlier. He ordered a quick and responsible response to coronavirus[26]. The order has a significant impact on the role of KCDC in its response to the coronavirus later, the first, experts group, and complementary actions by the whole government.

Presidential action progress: On March 19, the President headed a meeting to cope with the economic damage caused by the coronavirus. On April 9, the President held a joint meeting on the development of COVID-19 treatments involving industry, university and government ministries to encourage the

[24] http://health.chosun.com/site/data/html_dir/2020/05/13/2020051301377.html

[25] Yonhap News & Gallop, President's approval rate plunged to 29%… Minimum level after taking office June 19, 2015.

[26] Kim, S.H., on the last day of the Lunar New Year holiday, at Seoul Station… The birth of 'K-Corona Diagnosis', Money Today, March 25, 2020.

development of medicines and vaccines. Based on this leadership, various government ministries and government research institutes participated in the launch of the Government-wide Support Group for COVID-19 Medicine and Vaccine Development on April 27. This meeting makes I-U-G interaction in the field of medical technology. National leadership is the factor that has not been pointed out in the discussion of the sectoral innovation system.

Japan, which was close to China, where the coronavirus first broke out, and was considered to have a better medical system and technology than Korea, identified the first patient at a similar time. Japan, however, wanted a quiet response to the coronavirus ahead of the big event, the Summer Olympics. The silent response is no different from the secrecy that emerged in Korea's past responses. China is no exception to the confidentiality in the early emergence of the virus.

On the other hand, Taiwan[27] began inspections of travelers entering the country from the Wuhan region, the day after China announced the outbreak of unidentified pneumonia. People were also recommended to wear facemasks on January 1, three days later. On January 26, it issued a production order to the mask factory and sent soldiers to the mask production site. Also, entry into dangerous areas was suspended on January 26, and visitors should be self-isolation for 14 days from February 7. Taiwan adopts tight immigration control, quarantine, and social distancing very early. The leadership of the entire country beyond the medical field has been activated[28].

As shown in Figure 1, Taiwan recorded seven deaths as of June 15, 2020, and was rated as the world model country in response to coronavirus[29]. Taiwan's mask policy has had the effect of making Taiwan the world's second-largest exporter of masks[30]. However, the economic impact of the mask will not last.

VII. Conclusion

1. Summary and Limits

Korea's response to COVID-19 is summarized as follows: the first response is centered on technology and innovation. These include the development of diagnostic test methods and test kits, the use of ICT technology in

[27] https://www.boca.gov.tw/cp-220-5081-c06dc-2.html

[28] Barron, L., What We can Learn from Singapore, Taiwan and Hong Kong about Handling Coronavirus, Time, 2020.03.13.

[29] Griffiths, J., Taiwan's coronavirus response is among the best globally, CNN, April 5, 2020.

[30] 日產量挑戰 1000 萬，台灣如何做到全球第二大口罩產地？, BBC News 中文 2020-03-05.

epidemiological investigations, the technical response in the field, and the development of medicine and vaccines. These are unattainable phenomena without accumulated technology in the private sector[31]. The technical response also works in the parliamentary elections, education in schools at all levels, and the remediation process for economic damage caused by the coronavirus. However, these efforts are not the subject of this study, so further mention is omitted.

The second response is aggressive action just after the Chinese announcement, before the domestic outbreak; the third response is the open policy that induces voluntary participation of all subjects and people by opening all information[32]. Generally, only when the risks become apparent, technological responses emerge across society. However, if the response is late, the system is busy dealing with overflowing patients and cannot expect further innovation.

More critical is national leadership. Korea experienced several infectious diseases in the 2010s and appreciated the importance of the national leaders. However, in response to the coronavirus, the national leadership works suitably, asking for a preemptive response and trusting and supporting field experts. Although detailed analysis and data should be presented, at the beginning of the onset, the United States and Europe should be regarded as having failed to respond through misjudgment. Japan can be said to impede innovative response due to the existence of secrecy-type leadership.

Since this study deals with an infectious disease currently in progress, only about four months after it broke out, the research relies more on media and government materials than academic analysis and data. Therefore, the evaluation of specific items may vary over time, with various data being analyzed simultaneously.

Second, this study does not compare Korea's responses to other countries in depth. If such efforts are made, the characteristics of Korea's response will become more apparent, but the volume of material is too large, which should be addressed in other papers.

Thirdly, this study deals only with direct responses to coronavirus, not how social sectors respond or what are the socio-economic impacts. This task will be very considerable, so it is omitted due to paper limitations.

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[31] Many of the major private companies responding to the coronavirus come from researchers at the Daedeok Science Town, the cradle of Korea's early science and technology.

[32] Some experts point out that one of the characteristics of Korea's response is the positive response of the people. However, if the government treats everything secretly, there will be no response from the people. Korea's past responses to infectious diseases mentioned earlier are examples.

Forth, in this paper, the current President has appeared several times, explaining the factor of national leadership. This expression can be misunderstood as a political prejudice, but this paper is an academic paper.

2. Policy Suggestions - National Acceptance of Technological Innovation

Korea has been able to respond technically quickly because the private sector had so much grasp of technology. These technologies had not been used because of regulation, or reluctance to adopt them. These rejected technologies, however, have played a significant role during the coronavirus crisis.

Korea licensing is grounded on a legal basis; even though there are new technologies available, they cannot be used bypassing related regulations. Even domestic equipment and rapid diagnostic kits exported to about 50 countries were not used because relevant regulations were not in place in Korea. So-called regulatory problems existed (HelloDD, June 24)[33].

Similar cases exist in the semiconductor field. Korea's semiconductors rely heavily on Japanese parts and equipment technology, but one day (July 4, 2019), Japan suddenly banned the export of critical technology products due to diplomatic issues. However, this problem has been solved by domestic technology and technology from other countries (July 8, 2020)[34]. An attitude to use new technology is the way to strengthen technological innovation and competitiveness in a specific field.

[33] Kim I.H., Leading K-Bio, and 30 years of accumulation time, HelloDD, June 24, 2020.
[34] Cho, J.Y., Japan's exports to Korea are the lowest in 11 years… Corona and export regulation aftermath, Younhap News, July 8, 2020.

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