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Policies and innovations to battle Covid-19 – A case study of South Korea

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ABSTRACT

Objectives: To describe how health care crisis resulting from the COVID-19 pandemic in South Korea has led to innovation and changes to government policy. This paper presents the significant cluster events, relevant developments of innovation, and economical impact in Korea that could inform policy makers on how to respond to health crises in the future.

Methods: Health care, economy, epidemiological data are collected from various sources including the Korea Centers for Disease Control and Prevention (KCDC) or other government sources.

Results: The KCDC jointly with medical professionals developed a series of innovations such as 1) Full contact tracing and rapid testing with a 12 h turnaround and 10 min movement tracking systems, 2) transparent disclosure of all contract tracing data to the public through a central database, 3) Drive-Through and Walk-Through testing methods, and 4) a 4 tier patient severity index and community treatment isolation centers. Korea moved from the 4th in the world for total confirmed cases in March down to 76th in August.

Conclusions: Expedited enforcement of amended legislation acts to protect the healthcare workforce resulted in only 10 healthcare professionals contracting the virus while caring for Covid-19 patients. This has resulted in minimal human capital loss and the government was able to re-direct existing medical workforce to areas in need. The quarantine strategies implemented resulted in little need to lock down the whole economy but also limited the cost spent to gain a year of life to 193,848 Won (US\$163).

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Introduction

South Korea was one of the first countries other than China to record a Covid-19 case in January 2020. Till the World Health Organization (WHO) declared Covid-19 as a global pandemic on the 11th of March the total number of confirmed cases in Korea had exceeded 7755 patients. This number was just behind China, Italy, and Iran. While Korea had experienced a dramatic increase in confirmed cases in the early stages of the global pandemic, the government was able to quarantine the spread where the total confirmed cases per day has been on average 10 people for the last week of April. The steep decline of new cases in South Korea has been credited to the aggressive strategies that the Korea Centers for Disease Control and Prevention (KCDC) had put in place since the first patient was confirmed on the Jan/20. The mixture of fast and easily accessible diagnostic tests and technologies used for contact

tracing has been hailed as the two main factors to dampening the spread. Since Korea was hit by Covid-19 in early 2020, the methods developed, in Korea such as the drive-thru testing clinic, has been adapted in other countries that followed.

A reason this paper focuses on a single country that was affected by Covid-19 relatively earlier than other countries is that worldwide studies, such as Hale et al. [1] on 150 countries, fail to detail the correct policies such as recording a full lockdown in Korea whereas there was no such restrictions. In this paper we aim to provide a more accurate record of the health care system and the response taken by KCDC on three major cluster events that had prompted various new innovations in managing the spread of the virus. We also discuss how the economic effect of Covid-19 is compared to other Organization for Economic Co-operation and Development (OECD) countries. The early detection and treatment policy administrated by the KCDC, the extensive economic stimulus, and not relying on a forced lockdown limited the economic impact. Finally, in early May, Korea has relaxed social distancing rules and is starting to implement an exit strategy to reboot the economy post Covid-19. However, within a week of relaxing social distanc-

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Table 1
Four tier warning level used by KCDC.

Level	Description	Date level declared
Blue	Overseas report of Infectious disease documented	2020/Jan/08
Yellow	Domestic patient of infectious disease reported	2020/Jan/20
Orange	Limited spread of infectious disease	2020/Jan/27
Red	Community or national level spread of infectious disease	2020/Feb/23

ing requirements, a new Covid-19 cluster was found in the night-club district of Itaewon in Seoul. The response and early intervention on the cluster has limited any possibility of a second wave. As more countries are flattening the curve of confirmed cases, the Korean strategies and policy changes led by the KCDC could act as an important benchmark for policy makers around the world [2].

Health care system

National health care system

The South Korean healthcare system is run by the Ministry of Health and Welfare which aims to provide cheap care to all nationals and foreigners who contribute to the National Health Insurance scheme. The National Health Insurance Scheme is compulsory for each household and the premium is determined by the combination of household income and assets. This single-payer system was introduced in 2004 where the government agreed to subsidize 14% of the total funding each year. In the past decade, the national health care system has provided healthcare access to the entire population and has been ranked as one of the most efficient health care systems in the world [3]. To achieve the coverage for the whole population, health services covers up to 60% of health service and medication costs. Due to this receiving general medication coverage is regarded as highly accessible and effective where doctor and dental consultations per capita are both the highest among all OECD countries and life expectancy is ranked the 5th highest in the world at 82.7 years of age. (X6) However, since all services are not covered by the insurance scheme 67.6% of the population still maintain private insurance to cover the gap especially for costly operations such as cancer treatment. Another reason for the high demand of private insurance is that majority of the service providers in Korea are private providers. These for-profits seldomly use the referral system and recommend patients to services that are not covered by the national insurance or have high out-of-pocket (OOP) payments. Such practice has increased the tension between the government and private providers. Kwon, Lee, and Kim [4] state that while the national health insurance provides protection mechanisms the high OOP payments have remained a key policy issue. Reforms and subsequent extension of services and pharmaceutical items being covered by the insurance scheme has been effective but the overall OOP payments per household as a percentage of gross domestic product has still increased from 2.1% in 2010 to 2.7% in 2018. As of 2017, OECD reports that Korea has the 2 highest number of hospital beds per 1000 population at 12.27 beds among all countries which is behind Japan (13.05) and ahead of Germany [5]. The number of ICU-CCB beds per 100,000 population is 10.6 which is the highest in the Asian region [6].

Covid-19 response

KCDC uses a four-tier categorization of warning level for infectious diseases as shows in Table 1. From the first known confirmed patient it took a month till the warning level was raised to the

highest red level. During the Middle East Respiratory Syndrome (MERS) outbreak in 2015, the level was maintained at yellow.

During the 2015 MERS outbreak Korea had 186 confirmed cases where 38 patients died resulting in a fatality rate of 20.4%. Initially, the government refused to disclose information on any confirmed cases, such as which hospital the patients were being treated which was a breach of the “infectious disease control and prevention act” (IDCP act). Article 6 of IDCP act states the responsibility of the government to disclose information to the general public [7]. A survey found that 82.6% agreed that the government should follow the IDCP act and share information [8]. This event resulted in KCDC drastically changing policies and protocols when responding to newly infectious disease. The newly established Emergency Operations Center (EOC) aims to strengthen the country's capacity to respond to infectious diseases and operates 24/7 to receive notifications and collect information on the infectious diseases. Following the heightening of the warning level to Yellow in late January the KCDC has made information on Covid-19 transparent by holding a television broadcasted live press conference twice a day at 11am and 2pm. The morning briefing is chaired by the Vice-minister of Health and Welfare Kim Gang-lip and the afternoon session is run by the director of KCDC Jeong Eun-kyung. On Sundays only one press conference in the afternoon is held by the Minister of Health and Welfare Park Neung-hoo. In each session an up to date statistics on newly confirmed cases are provided. Other information such as government policy and guidance, personal hygiene recommendations, progress of development of vaccination are provided.

KCDC also created a Covid-19 24/7 hotline and worked with healthcare providers to establish a national network of 638 public health centers and medical institutions operate screening stations, of which 95 percent (606 stations) are equipped to collect specimens onsite [9]. Simultaneously the government granted expansion of production of real-time reverse transcription polymerase chain reaction (rRT-PCR) diagnostic testing kits by pharmaceutical companies which increased the daily testing capacity from 3000 per day in February to 20,000 in April with a turnaround time of 12 h. The cost is free when a patient receives a referral from a doctor and if not can cost up to 160,000 Won (US\$132). However, if a self-elected test returns positive the cost is fully reimbursed by the government.

While Korea had a dramatic increase in newly confirmed cases in late February, the government did not enforce any domestic travel or visiting restrictions (lockdown) such as preventing visiting shops, friend, or opening of business. Instead the government recommended that people in highly affected areas to stay at home and to practice social distancing [10]. The only formal restrictions were on confirmed patients, when specific clusters were identified, and on schools¹ and universities. Table 2 presents the mobility report from Google [11] which chart movement trends over time by country, across different categories of places. The table shows the maximum decrease in mobility for Korea and comparable developed countries during Feb/15 to May/30 compared to the baseline period of Jan/3 to Feb/6. The table shows that while no formal lockdown was enforced in Korea; movement to retail, grocery, parks declined as much as countries such as Australia which had a substantive lockdown period such as closing state borders and prohibiting domestic international air travel.² However, the amount of decrease in transit stations and workplaces are less severe in Korea which shows that government advice on limiting travel other than for work purposes were well followed. The im-

¹ On May/20, high schools returned to face to face learning, but elementary schools remained closed till June.

² Mobility changes during weekends or public holidays have been excluded from the analysis.

Table 2
Google Covid-19 mobility report by country from Feb. 15 to May.30.

	Retail & recreation	Grocery & pharmacy	Parks	Transit stations	Workplaces	Residential
Korea	-41	-18	-38	-36	-16	-2
Australia	-45	-19	-43	-63	-42	-2
Italy	-92	-90	-84	-86	-86	-1
Germany	-77	-51	-49	-68	-47	0
UK	-85	-46	-52	-75	-70	-1
US	-49	-22	-23	-54	-52	-1

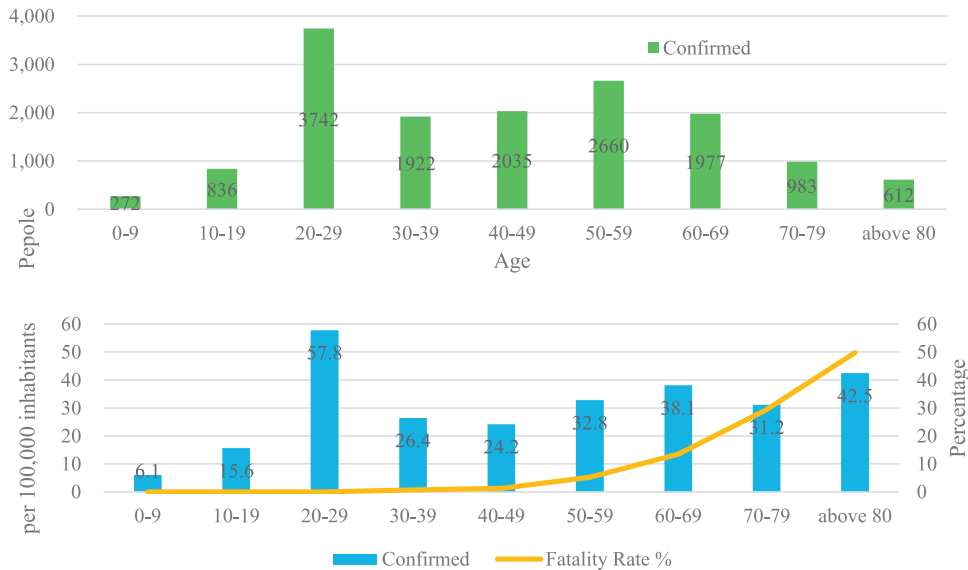


Fig. 1. Confirmed cases by age group – Total and per 100,000 inhabitants.

pact of not limiting people to work is further discussed in economic impact analysis in section 5.

On Jun/5, WHO announced that face masks should be worn where COVID-19 is widespread and physical distancing is difficult [12]. Prior to such announcement majority of the Asian countries advised that face masks be used. In Korea, a large portion of face masks were exported overseas prior the steep increase in confirmed cases in late February. Due to this there were difficulties in supplying enough masks. The government intervened and set strict laws prohibiting hoarding of face masks, put a restriction on the number masks a person can purchase each day, and limited the price of masks [13].

Covid-19 trends and clusters

General trend, mortality rates, and comorbidity

As of Aug/15 the total number of confirmed cases are 15,039 cases. Male patients are 6875 and female patients are 8164 cases which are 45.71% and 54.29% of total cases. Out of each gender group 162 male patients and 143 female patients passed away. The fatality rate is each 2.36% and 1.57% which shows a higher rate for male patients. A more detailed confirmed cases and fatality rate for each age group is presented in Fig. 1.

The cumulative trend in confirmed cases from Feb/17 onwards for every three days is shown in Fig. 2.³ The figure is divided into to four regions to capture the impact of 2 epicenters and returning people from overseas countries (overseas). The 2 major epicenters are 1) the Daegu and Gyeongsang-bukdo linked to the Shinchunji

religious cult and 2) the Capital region which includes Seoul, Incheon, and Gyeonggi-do. The first epicenter contributed to almost 90% or more of the confirmed cases in February and March.

During March and April isolated clusters in the Capital region, where 50.15% of the Korean population is located, contributed to the increase in confirmed cases from Mar/9 (Gurogu telemarketing center). The daily change in confirmed cases and the four clusters are labeled in Fig. 3. As shown in Fig. 3, by early May, the number of daily confirmed cases had decreased to less than 10 cases per day. The stabilizing of community spread was already being observed where on Apr/15 the government held the 21st parliamentary national election. Two weeks after the election the minister of health and wealth declared that there was no community transmission post-election even though 29 million out of 45 million eligible voters went to the polls. However, a few days after on May/6 (Itaewon nightclub district), and from Jun/3 (Richway door-to-door sales company) multiple cluster in diverse communities in the capital region emerged leading to 426 new cases of community transmission in June where 96.7% were from the capital region.

Fig. 4 represents the number of tests that were conducted each day where the confirmed and negative cases are shown on the left axis and the confirm rate is shown on the right axis. The effort by KCDC to target highly affected regions and to pro-actively preventing the spread of the virus, are notable where there is an initial peak of tests in early March followed by a secondary peak from May. In the following sections this paper will discuss the impact of the two epicenters in detail.

Another source of confirmed cases is from returning residents from overseas. A total of 17.5% of the confirmed cases are from overseas travelers. South Korea’s geographical proximity to China and the fact that the total trades with China is 25% of all exports and 21% of all imports led to around 13,000 people trav-

³ While there are daily data available, the authors use every 3 days’ data in this graph for visual convenience.

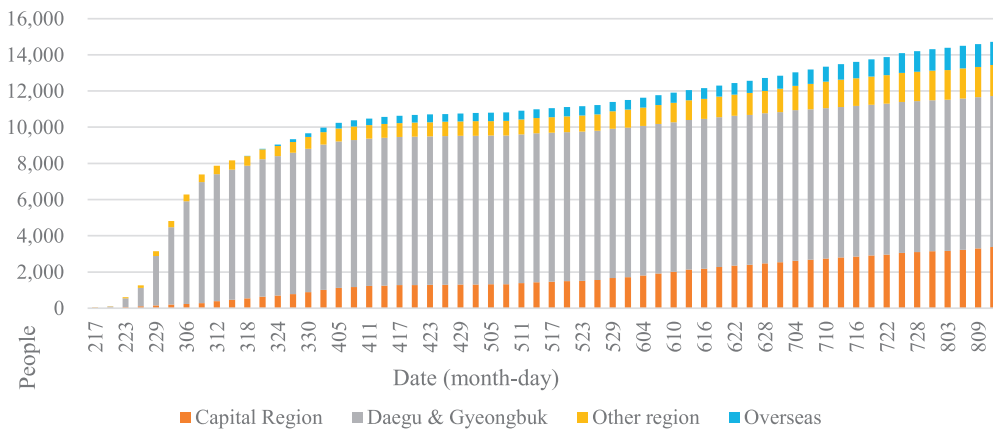


Fig. 2. Cumulative Covid-19 confirmed cases by region (every 3 days from Feb/17).

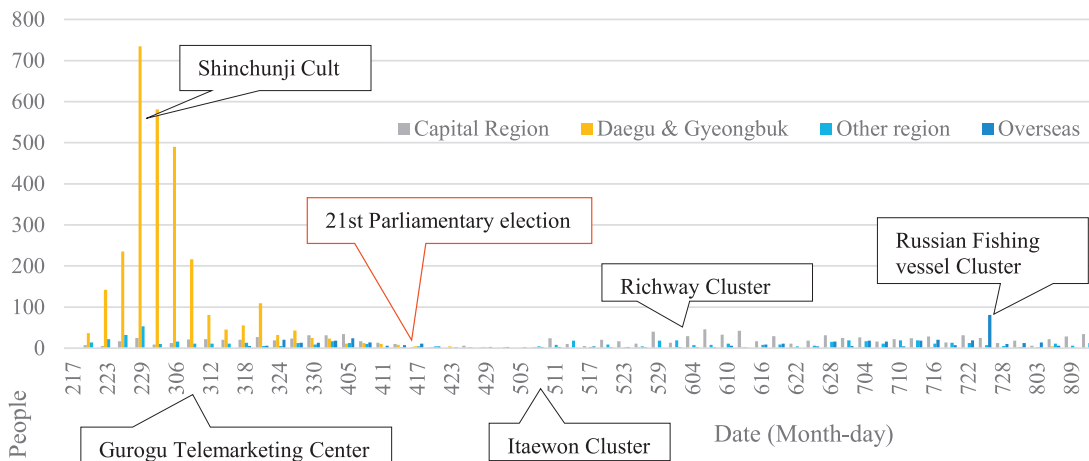


Fig. 3. Daily confirmed cases by region (every 3 days from Feb/17).

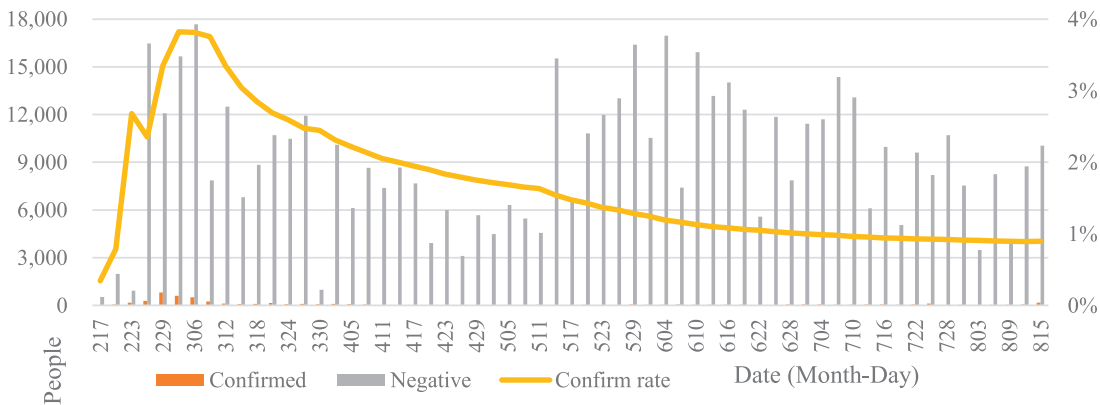


Fig. 4. Covid-19 Test daily statistics (every 3 days from Feb/17).

eling from China to Korea daily prior to Covid-19. While thermal imaging system existed in major international airports in Korea the asymptomatic nature of the virus has limited the effectiveness of any airport screening [14]. The first patient was confirmed on the 20th of January who was a Chinese tourist experiencing a flu like symptom. The following cases were mostly Korean nationals who had been working in Wuhan before returning to Korea. While there were requests to the government to quarantine or limit people who had been in China the government decided not to implement any restrictions to travelers from overseas till Apr/1 where all inbound people were asked to self-isolated for 14

days. The self-isolation was introduced as the overseas travelers had been increasing noted as a source of newly confirmed cases during late March [15]. The geographical location of departure in Table 3 shows that 51.5% of the overseas cases are from the American and European continent which had become the areas of steep increase of Covid-19 cases from March.

On Jun/25, KCDC disclosed detailed information on comorbidity, source of infection, and the location of all 282 death chases. Table 5 shows that 5 patients out of 282 deaths did not have a pre-existing illness. 53.5% of deaths were male and 46.5% of deaths were female. Most patients had either a circulatory disease such

Table 3
Confirmed cases from returning overseas travelers by country and nationality (Aug/15).

Classification		Confirmed Cases
Total		2629
Country	China	18
	Asia excluding China	1194
	Europe	532
	America	822
	Africa	58
	Oceania	5
Nationality	Korean nationals	1715
	Foreign nationals	914

as high blood pressure or a metabolic disease such as diabetes. A 54.6% of the patients contracted the virus while being a patient of a health(aged) care institution or while being hospitalized to treat other illnesses. Table 5 shows the 5 most common chronic diseases for in 2016 the Korea National Health and Nutrition Examination Survey published by KCDC [16]. When compared to the existing chronic disease, the three highest comorbidity are also the top three chronic diseases in Tables 4 and 5. For example, hypertension is common among 7 out of 10 people who are above 70 and was the most common illness that the deceased had. The third highest chronic disease is mental illness in both Table 4 but data from January to April 2020, during the heights of the Covid-19 crisis, the suicide rate decreased by 1.5% when compared to the previous year [17].

According to National Health Insurance Service [18,19], the top 25 percent longest hospitalized patients took 43 days to recover and the average cost for treating patients was 4.6 million Won (US\$3900). A light patient cost around 220,000 Won (US\$182) whereas the critically ill spend around 640,000Won (US\$528) per day. The average cost to treat an intensive care patient was 70 mil. Won (US\$57,562). Table 6 shows the degree of different treatment required to treat patients. For patients older than 60 around 17% needed at least oxygen treatment For patients over 80, more than half needed critical or intense treatment. Using the death by age in Fig. 1 of 305 death and the residual life in Table 6, we have calculated the total life years lost to Covid-19 which was 4778.6 life years. The average life years lost for each death was 15.67 years once the total was divided by the number of deaths. Through the same method the average life years saved was 23.73 years, which is the expected additional years the recovered patient is expected to have gained from being treated. Using the cost of treatment per patient from the NHIS (4.7mil Won) then dividing this by the average life years saved, the average additional life year gained cost 193,848 Won (US\$163). On Mar/17 there was a 2.1 trillion Won new spending including disease control and epidemic prevention and to date to support treatment and prevention [21].

Cluster event 1 – Shincheonji religious cult

For the first four weeks from patient one the total number of confirmed cases in Korea was 30. The slow increase in numbers was regarded as evidence of the virus being effective controlled. However, patient 31, who was tested on Feb/17 and confirmed positive on the Feb/18, was the super-spreader leading to a major outbreak in the Daegu and surrounding Gyeongbuk region in the south east part of Korea. The size of Daegu and Gyeongbuk region is 19,030 km² and is comparable to Beijing which is 16,410.5 km² in size. As soon as patient 31 was confirmed KCDC, contract traced her movements for the past two weeks [12] and was able to produce a list of 9336 people who had close contact and needed to be tested. Patient 31 had developed symptoms on Feb/10 while being in an oriental medicine hospital from the 6th following a traf-

fic accident. Doctors recommended her to take a test on Feb/15. However, she refused to receive tests and during her hospitalization period she attended services at the Daegu branch of the Shincheonji Church of Jesus. In the Shincheonji doctrine, it is a sin to be ill and illness is regarded as proof of weak faith which motivated the followers to continue attending services while hiding their illnesses. Out of the 9336 close contact list 9300 people were followers of the cult. As the service in Daegu was attended by followers from around the country the government planned to track the 9336 people and those who had contacted the 9336 people. However, there was a major challenge, Shincheonji followers are viewed negatively in mainstream Korean society and followers are known to hide their religion, even from family, to maintain their social status. Due to this even though the government offered free testing for all Shincheonji followers, the voluntary adherence was low and eventually the government raided the HQ of the cult to gain the full followers list.

From the patient 31, 790 more new cases were confirmed in the next 7 days. Another 3500 cases were confirmed in the following week. The fast increase in numbers in a specific regional area meant that the hospitals had difficulty caring for all confirmed cases [23]. Especially, since each hospital needed to take care to limit exposure of non-Covid-19 patients to the confirmed patients. The extra demand of isolated space and beds put a strain on the amount of medical resources available. Eventually, Covid-19 patients were turned away and given instructions to wait till a bed was made available. On Mar/3 a patient died at home while waiting for a bed where the patient had just two hours left till being hospitalized. Another death at home was recorded soon after. To prevent such deaths KCDC developed a 4-tier patient severity index from asymptomatic to severely ill and made asymptomatic or light symptom patients to be isolated at non-hospital facilities. This led to only 10% of confirmed patients being hospitalized and in the following two weeks the number of patients waiting to be hospitalized dropped from 2200 to 124. The non-hospital facilities included 16 community treatment centers, or life treatment centers, were established to manage mild cases where government and private sector owned dormitories and training centers were turned into isolation facilities. A major policy change due to this cluster event was the amendment of three legislation acts on Mar/3 and was to be enforced from Apr/4 [24]. One of the important amendments were provisions such as legally preventing health care workers re-using single use private protection equipment. While enforcement of any acts needed minimum three months from declaration, the expedited enforcement assisted in protecting the valuable medical workforce. Till April, only 2.36% (234 patients) of confirmed total cases were health care workers which was significantly lower than countries such as Spain (16.6%), UK (14%), or Italy (10%) [25]. Out of the 243 patients 43% were from community transmission and only 10 patients were from exposure to the virus while looking after confirmed patients. This has resulted in minimal human capital loss and the government was able to redirect existing medical workforce to areas in need.

Cluster event 2 – Guro telemarketing center

The Guro telemarketing call center based in Seoul is a case where proximity amongst desks at work resulting in a new epicenter [26]. On Mar/8 KCDC was notified of a patient who was working in a telemarketing center at a high-rise building. The company had 811 staff working across 4 levels of the building. On Mar/9 KCDC started testing all staff, 203 residents of the building, 20 visitors and another 111 people working at other companies in the building. Eventually 158 cases were confirmed where 97 were staff working at the call center. 94 out of the 97 were located on the 11th floor which had a total of 216 staff. This meant that the hot-

Table 4
Information on deaths – Comorbidity, source, and location of death.

Panel A. Comorbidity (multiple diseases are possible)		
Circulatory system disease	215	76.20%
Endocrine and metabolic diseases	134	47.30%
Mental illness	125	44.50%
Respiratory diseases	63	22.40%
Urinal/Genitourinary system diseases	46	16.40%
Cancer	40	14.20%
Nervous system diseases	20	7.10%
Digestive system diseases	12	4.30%
Musculoskeletal disorders	13	4.60%
Blood and hematopoietic diseases	5	1.80%
Total	276	
Panel B. Infection Route		
Health(aged) care/hospital	154	54.60%
Shinchunji Religious Cult	31	11.0%
Contacts of confirmed cases	25	8.90%
Overseas related	1	0.40%
Investigating	71	25.20%
Total	276	
Panel C. Location of Death		
Hospital Room	262	92.90%
ER	17	6.20%
Home	3	1.10%
Total	0	

Note: Data released on June/25/2020.

Table 5
Existing common chronic disease in Korea.

Male, Female, Male above 70 and Female above 70 (% of population)				
Most common chronic disease	M	F	M>70	F>70
Hypertension - circulatory system disease	35	22.9	64.2	72.5
Diabetes - metabolic diseases	12.9	9.6	26.4	30.9
Mental illness	28.2	30.6	8.6	21.7
Chronic obstructive pulmonary disease - respiratory diseases	19.6	5.8	55.2	14.5
Urinal/Genitourinary system diseases	4.2	5	19.5	23.6

Source: 2016 Korea National Health and Nutrition Examination Survey - KCDC.

Table 6
Treatment type required for Covid-19 patients.

Age	Minimal (%)	O2 treatment (%)	Ventilation/Ecmo (%)	Death (%)	Residual life
0–9	100.0	0.0	0.0	0.0	82.7
10–19	99.6	0.2	0.2	0.0	73
20–29	99.2	0.7	0.1	0.0	63.1
30–39	98.2	1.3	0.3	0.2	53.4
40–49	97.0	2.6	0.2	0.2	43.7
50–59	91.7	6.7	0.8	0.8	34.2
60–69	82.9	12.0	2.1	3.0	25.2
70–79	62.3	21.8	3.0	12.9	16.7
above 80	41.8	21.8	1.6	34.8	9.3

Source: KCDC July/8 and Statistics Korea (Residual Life table).

desk environment and the nature of work being the staff needed to communicate with clients throughout the day increased the likelihood of secondary infections. While the patients shared the elevators, lobby and other facilities with residents of the building living on the 13th floor to the 19th floor no resident was found positive. From these results, Park et al. [26] report that “duration of interaction (or contact) was likely the main facilitator for further spreading”

A similar example to the Guro cluster is the Zumba fitness dance exhibition and classes where 8 instructors contracting the virus at a national workshop returned to their region and spread the virus. Jang, Han, and Rhee [27] show that intense physical exercise in densely populated sports facilities should also be avoided.

Cluster event 3 – start of a second wave?

In the first week of April the number of newly confirmed cases started to stabilize to under 50 cases which further decreased to less than 10 people for the last week of April. This decrease in new cases and the long national holiday period from Apr/30 to May/5 meant that a wider discussion of relaxing social distancing rules led to the government deciding to recommend a new routine of ‘distancing in daily life’ starting from May/6. On May/6 a new patient who had symptoms during the holiday period emerged. This patient, while being ill from May/2, traveled across 4 cities and visited highly dense facilities which included a nightclub at Itaewon in Seoul. A close contact analysis showed that the patient’s two friends who accompanied the patient were also tested positive on

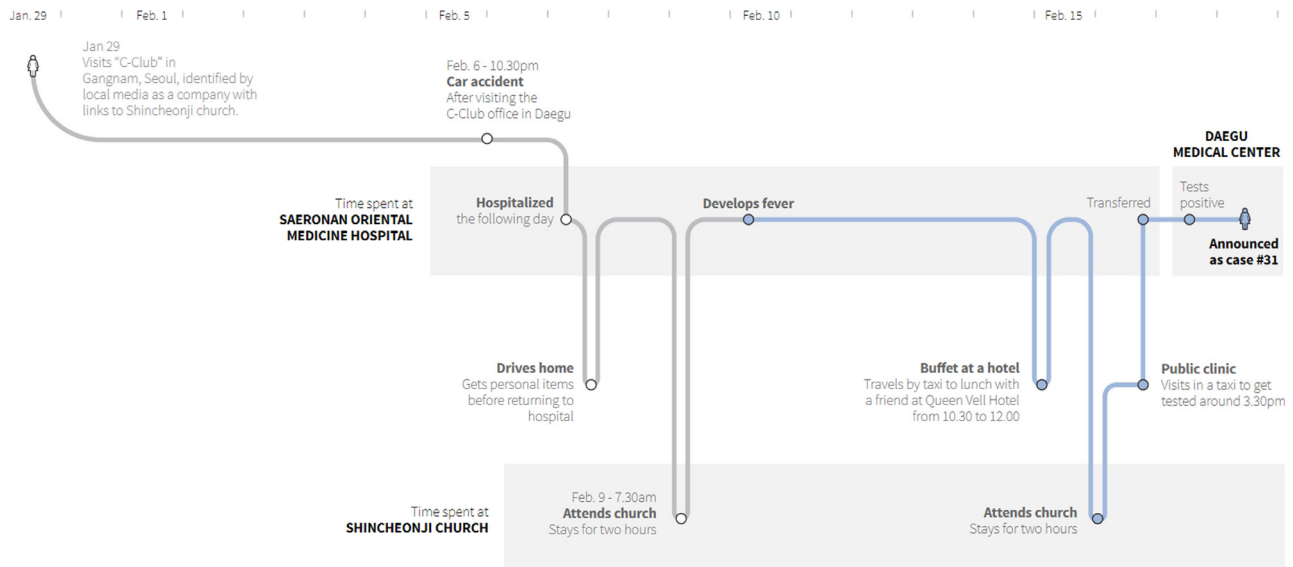


Fig. 5. 14 days contact tracing of patient 31.

Source: <https://graphics.reuters.com/CHINA-HEALTH-SOUTHKOREA-CLUSTERS/0100B5G33SB/index.html>.

May/7. Within 20 days the total positive cases increased to 255 patients. The average number of daily cases due this cluster exceeded the national average of new cases in the previous week. The Itaewon nightclub cluster was linked to new patients in their 20s and 30s. This age group had recorded no deaths to date and inattention to social distancing rules, which were to be lifted, contributed to the emerging of the cluster.

On the other hand, the Richway cluster in the capital region had the opposite characteristics where 90% of the patients were aged 40 or above and 45% were above 65. Richway was a door-to-door sales firm which commonly held community gatherings to promote their products. In the first two weeks of confirming the first patient in this cluster 164 positive cases were reported. Interestingly, from the early transmission stage only 40 patients were visitors to the Richway facilities. The rest of 124 patients were secondary or tertiary infection among the elderly and retired who spent time with their peers. The two major clusters emerging in the capital region resulted in the reproductive rate increasing from 0.5 prior to the long holidays to 1.2 in early June. The government banned facilities such as nightclubs operating following the new clusters and offered free testing to the general public. As of date, the government is continuing extensive contact tracing and testing of all contacts for every new patient and has been able to prevent a second wave by limiting the daily new cases to 50 per day.

Major innovations to prevent spread of Covid-19

Contact tracing using mobile phones and CCTVs

KCDC closely follows the infected person's movements over the preceding 14 days. Fig. 5 is an example of the 14 days contact tracing by date and hour for patient 31 in the Shincheonji cluster. To more accurately trace the movement of the patient both GPS and cell tower data are used when available. To supplement the mobile device data, credit card usage and CCTV footage are used. While the usage of such data could breach individuals' privacy, the usage of the credit cards and CCTV were effective in cases where potential close contacts did not come forward (Shincheonji Cult cluster) or when a patient visited a high-density location (Itaewon cluster). Using contact tracing data, the government established a database which provide transparent information of the locations and dates

that the patient visited. Each patient is given to numbers, one the national number and one for the local council number. The local councils use the patient movement database and provide as separate regional database to residents to easily search any potential contact with a new case. Some councils use residents' mobile phone details recorded in the council system to send text message alerts when a new infection emerges in the area where they live or work. Even though KCDC traced the movement of each patient, the process was slow due to the nature of manual handling of data which took more than a day. This led to KCDC developing an automated public health surveillance which uses all form of digital data such as card transaction, mobile phone location data and allow a full recollection of any patient's movement for the last 48 h in just 10 min [28]. From this central system and the transparent information dissemination process, anyone could check if they were potential exposed to the virus and needed to be tested if not already contacted by KCDC. The database has assisted early research on clusters by providing an accurate contact mapping (see Park et al., 2020 [26]; Jang et al., 2020 [27]). Details of the location and time each patient visited for last 14 days are provided. Other information such as the residential suburb or which hospital the patient visited is provided.

While foreign press questioned whether the new public health surveillance system could breach privacy rights by accessing too much private information. [28], the government explained that it had witnessed strong support for full information disclosure during the MERS incident in 2015 [8]. A survey by the Institute for Future Government in Mar/10 revealed that 84.4% agreed that disclosure of information of confirmed cases is more important than personal information protection during the Covid-19 crisis [29]. Another trade-off to consider is if information was not shared to the public to manage the infectious disease then a full-lockdown and travel restriction would have been inevitable for Korea [29–31].

Drive through, walk through, and rapid full testing policy

One of the most significant innovation during the Covid-19 crisis was the development of the drive through (DT) and walk through (WT) testing method. The DT method developed by Dr. Jin Yong Kim and first tested at first Kyungpook National University Chilgok Hospital located in Daegu on Feb/23. (see Kwon et al.



Fig. 6. Drive-thru Screening Stations.

Source: <https://www.croakey.org/covid-19-lessons-from-south-koreas-quick-response/> [22].

[32] for further details) The DT center shown in Fig. 6 can be understood as a Screening Clinic but where testees arrive in their own car and limit exposing medical staff, requiring a disinfection of the path the testee passed, and most importantly prevention of cross-infection between testees in the waiting space. A DT center has four components which are registration, examination, specimen collection, and further instructions. From the registering to leaving the center would take about 10 min which is 6 times faster than a normal testing facility. The WT method is where a booth is setup for medical staff so that the staff are separated from the testee. Disinfection and ventilation of the booth should be done after every use, but the overall process takes around 20 min which again is 3 times faster than a normal testing facility without proper staff protection. Choi et al. [33] compares the DT and WT methods and suggests that both methods are particularly useful where personal protective equipment (PPE) is in shortage.

Following the Guro breakout the KCDC and the government was able to demonstrate that sending a quick response team of dedicated healthcare staffs for rapid virus screening tests at the site is effective in conducting a full testing of all close contacts of a newly confirmed case. During May as the Itaewon breakout spread among the local community, a fifth infection from the cluster was an employee working at a logistic center of Coupang. Coupang is the largest e-commerce online with an annual revenue exceeds US\$4 billion. The logistic center at Bucheon has 3600 employees and the fact that an infected employee could contaminate a delivery package which can be sent to anywhere in Korea, the city of Bucheon requested a rapid testing site to be setup. Fig. 7 shows the testing site where within 4 days all 3600 employees were tested. The city council made sure that all medical staff were given proper support by tasking non-medical civil servants to assist the medical staff. The council also ensured that the medical staff were able to have adequate rest by providing a four-star hotel for accommodation. While the case shows that the rapid testing technologies effectiveness in testing a large amount of testees but it demonstrated that non-medical staff can support the medical staff to share the burden. Another outcome was that this successful case initiated a further discussion of establishing a rapid response team that can be on-call and sent to any potential mass testing site in the future.

Economic impact

The Korean government announced three special budgets to deal with the economic fallout from Covid-19. The first stimu-



Fig. 7. Bucheon Coupang logistic center rapid testing site.

Source: https://twitter.com/hosa_Y/status/1265980395952226305.

lus package was 11.7 trillion Won (US\$9.82 billion) announced on March/4. This package exceeded the amounts that were raised for the 2003 SARS outbreak (4.2 trillion Won) and the 2015 MERS outbreak (11.6 trillion Won). The areas that the extra budget was used was first to advance infectious disease treatment capacity and to provide financial support to medical institutions. Second to revitalize the economy by providing cheap loans to small medium enterprises and to provide support for low-income households and the elders. The second extra budget was 7.6 trillion Won (US\$6.3 billion) announced on April/16. The stimulus package was to be directed to each household that rank in the bottom 70 percent of gross income. 14.78 million households were expected to receive up to 1 million Won for a family of four. Instead of cash payments, the government decided to handout shopping coupons and gift certificates that can be used in the regional markets. The third package was announced on June/3 which is to be 35.3 trillion Won (US\$28.8 billion) equivalent to 14% of Korea's GDP. This package is to be used directly to project jobs and supplement the areas that were supported in the first two packages. Additionally, 5.1 trillion Won in the third package was dedicated to the 'Korean New Deal' which invests in digital and environmental infrastructure and industries. Overall, the Korean government has so far announced a total of over 277 trillion Won (US\$23.6 bil. and 14.4% of GDP) sup-

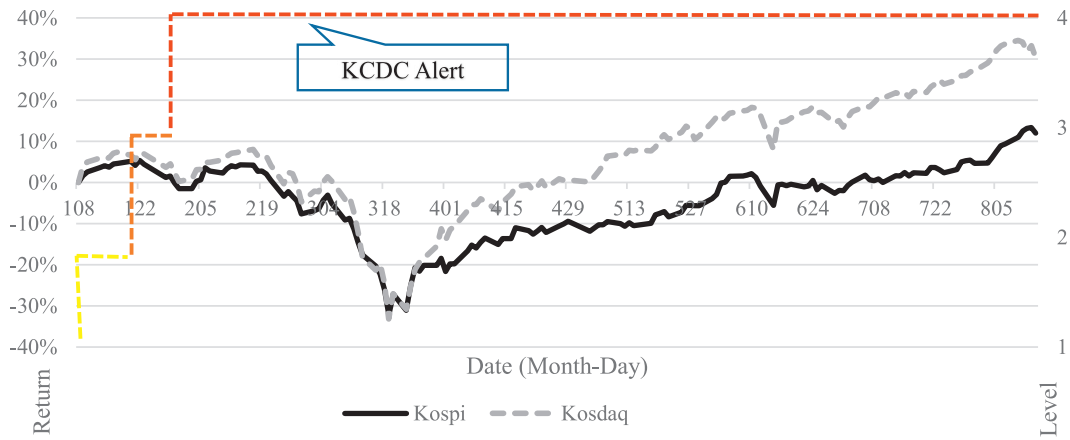


Fig. 8. Stock market index cumulative returns since Jan 9 2020.

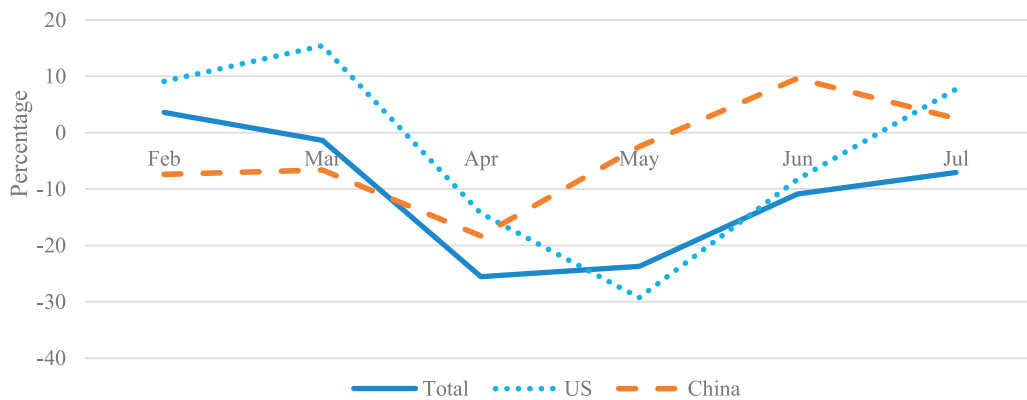


Fig. 9. Annual change to month in Import Export.

port measures to mitigate the impact of the Covid-19 virus including liquidity provisions and credit guarantees [34].

The overall impact of Covid-19 was relatively soft on the Korean economy where the government revised the yearly economic growth for 2020 to 0.1% from 2.4% [34]. The anticipated growth would be the worst year since the Asian financial crisis in 1998. The projected change in GDP is -1.2% [17] and if a second wave of infections is to occur, the change is to be -2.5%. These figures rank Korea as the least affected economy out of all OECD countries where the average for all OECD countries are expected to be -7.5% (-9.3%) respectively. The second economically least hit country is Australia at -5% (-6.3%) but this figure did not consider the re-introduced lockdown in Victoria in July.

While the Korean economy did not experience a severe contraction, the Bank of Korea decided to decrease the Base Rate by 50 basis points from 1.25% to 0.75% on the March/16 and once again by 25 basis points to 0.5% on May/28. The overall stock market response followed a similar decline and increase compared to the US stock market. The two local indices are the KOSPI index and the KOSDAQ index are shown in Fig. 8. The line bars are the KCDC infectious disease alert levels. Both indices are now above the pre-Covid levels.

Fig. 9 shows the export amounts compared to the previous year by months for all countries, US, and China. While the export activity was negatively affected during April to Jun, exports to US and China is recovering to previous year's levels. Both Figs. 9 and

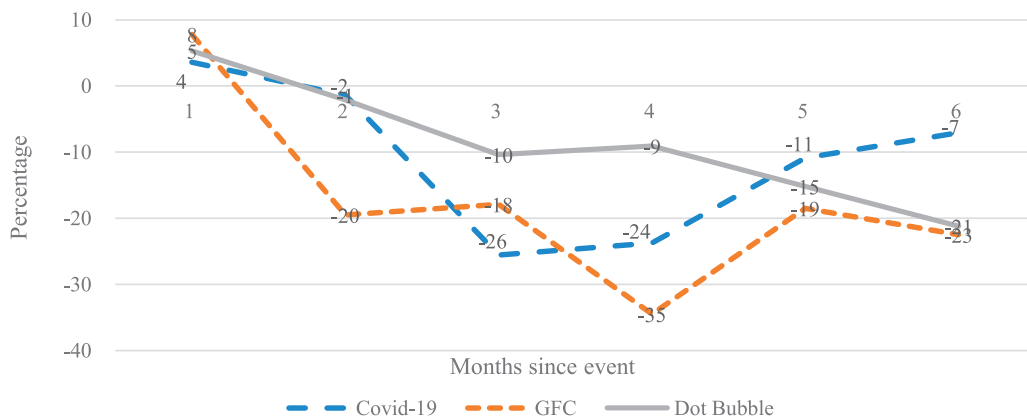


Fig. 10. Recovery from major crises.

10 show that the overall Korean economy had taken a hit during the height of the Covid-19 pandemic in March to April, but most of the business activities have returned. In Fig. 10, the overall export activities are compared between other major crises such as the Global Financial Crisis (GFC) in 2008 or the Dot.Com Bubble in 2001. The recovery within the first 6 months is notably different where by the six months from initial event date, the export amount during the other two crisis were still at more than 20% less than the previous year.

Another way of calculating the impact of medical and policy intervention is projecting the expected patients when no intervention was taken place. Hsiang et al. (2020) predicts that if the Korean government did not intervene the total amount of confirmed cases would have been 12 million people by Apr/6 which is 1 out of every 5 people in Korea [20]. Using the fatality rate of 1.96% the total expected death would be 240,000 people. As 277 trillion fiscal injection contributed to preventing such losses, the value of statistical life is approximately 1.1 billion Won (US\$1mil).

Conclusion

This paper presents the three significant cluster events and relevant developments of innovation. The quarantine strategies implemented resulted in little need to lockdown the economy but also limited the cost spent to gain a year of life to 193,848 Won (US\$163) and the value of statistical life calculated from the three fiscal stimulus packages is 1.1 billion Won (US\$1mil). For this paper we record what Korea Centers for Disease Control and Prevention (KCDC) jointly with medical professionals have developed. The innovations such as 1) Full contact tracing and rapid testing with a 12 h turnaround and 10 min movement tracking systems, 2) transparent disclosure of all contract tracing data to the public through a central database, 3) Drive-Through and Walk-Through testing methods, and 4) a 4 tier patient severity index and community treatment isolation centers are some of the on-demand changes that were made due to new epicenters emerging. Through these innovations Korea moved from the 4th in the world in terms of number of confirmed cases in March 2020 down to 76th in August. The importance of the different events is that event led to the Korean government to expedite health care worker's protection laws, or new laws to penalize patients who do not follow required self-isolation, or implement a faster surveillance system. As the number of newly confirmed patients dramatically decreased to less than 10 in mid-April the government announced plans to reduce extra 7500 beds that were added to hospitals and community treatment centers to 1500 beds in 4 phases [35]. Overall, the results from innovative technology but expediting policies that were crucial in overcoming the virus can be of strong interest to policy makers around the world in implementing an infectious disease response strategy [36].

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