The impact of containment policy and mobility on COVID-19 cases through structural equation model in Chile, Singapore, South Korea and Israel (#82138)

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The impact of containment policy and mobility on COVID-19 cases through structural equation model in Chile, Singapore, South Korea and Israel

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Objectives: The study aims to understand the impact of containment policy and mobility on COVID-19 cases in Chile, Singapore, South Korea and Israel. To provide experience in epidemic prevention and control. **Methods:** Structural equation modeling (SEM) of Containment policies, mobility, and COVID-19 cases were used to test and analyze the proposed hypotheses. **Results:** Chile, Israel and Singapore adopted containment strategies, focusing on closure measures. South Korea adopted a mitigation strategy with fewer closure measures, focusing on vaccination and severe case management. There was a significant negative relationship among Containment policies, mobility, and COVID-19 cases. **Conclusion:** To control the COVID-19 and slow down the increase of COVID-19 cases, countries can increase the stringency of containment policies when COVID-19 epidemic is more severe. Thus, countries can take measures from the following three aspects: strengthen the risk monitoring, and keep abreast of the COVID-19 risk; adjust closure measures in time and reduce mobility; and strengthen public education on COVID-19 prevention to motivate citizen to consciously adhere to preventive measures.

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Abstract

Objectives: The study aims to understand the impact of containment policy and mobility on COVID-19 cases in Chile, Singapore, South Korea and Israel. To provide experience in epidemic prevention and control.

Methods: Structural equation modeling (SEM) of Containment policies, mobility, and COVID-19 cases were used to test and analyze the proposed hypotheses.

Results: Chile, Israel and Singapore adopted containment strategies, focusing on closure measures. South Korea adopted a mitigation strategy with fewer closure measures, focusing on vaccination and severe case management. There was a significant negative relationship among Containment policies, mobility, and COVID-19 cases.

Conclusion: To control the COVID-19 and slow down the increase of COVID-19 cases, countries can increase the stringency of containment policies when COVID-19 epidemic is more severe. Thus, countries can take measures from the following three aspects: strengthen the risk monitoring, and keep abreast of the COVID-19 risk; adjust closure measures in time and reduce mobility; and strengthen public education on COVID-19 prevention to motivate citizen to consciously adhere to preventive measures.

Keywords: COVID-19, structural equation modeling, mobility, Containment policies

1 Introduction

COVID-19 still negatively affects normal life. WHO recommends a containment strategy in the first stage of a pandemic, especially by actively tracing and isolating close contacts to prevent their transformation into a chain of transmission, to stop as much transmission as possible, and eventually make the pandemic disappear. As of May 1, 2022, there were 513,52,166 confirmed cases and 6,261,385 deaths worldwide.

Chile is a model country in the fight against COVID-19, making full use of big data to aid government decision-making, establishing a platform for monitoring the movement, a proactive search system for asymptomatic cases, and a COVID-19 vaccine antibody response monitoring program[1,2]. Chile is active in vaccination, which is one of the highest vaccination rates in the world[3]. In the early stage of COVID-19, Singapore adopted strict border containment measures through the containment strategy and initiated a graded diagnosis and treatment policy[4]. Singapore began lockdown measures to isolate migrant workers on April 7, 2020[5]. After the vast majority of citizen vaccinated in 2022, Singapore was no longer pursued the "clean-up strategy" and declared coexistence with COVID-19. South Korea, in the early stages of COVID-19, implemented a containment strategy, escalated public alert levels, and entry control procedures. In response to cluster outbreaks, South Korea implemented a strict lockdown and 14-day quarantine[6]. Entering the Omicron, South Korea eased social restrictions, leading to a spike in COVID-19 cases. On April 30, 2022, 330,000 people per million in South Korea had been infected. Israel is a superior student of vaccination, being the first country to fully vaccinate, the first to administer vaccine booster shots and the first to prescribe the fourth dose of vaccine[7,8]. Israel's COVID-19 strategy is a mixture of vaccine policy and closure policy. During the Omicron period, Israel was the first country who declared lockdown. But on March 1, 2022, it lifted most of the restrictions on COVID-19, including the "gathering restriction".

In this study, to provide opinions and suggestions on restoring normal production and life order, the structural equation model(SEM) of Containment policies, Mobility, and COVID-19 cases was constructed to test and analyze the proposed hypotheses.

2 Research framework

Containment policies for COVID-19 were first implemented in Wuhan, China on January 23, 2020. These policies are collectively known as the Wuhan City Containment policy and include home quarantine, strict exit screening measures closure, a shutdown of public transportation, a ban on leaving Wuhan, and other Containment policies[9,10]. Scholars have used a variety of statistical methods and models to analyze the effects of certain periods and geographic closure measures. In studies of early stages of COVID-19, it was shown that conducting a social restriction policy and limiting social distance was effective in reducing COVID-19 cases[11,12]. Vincenzo Alfano's research estimated the impact of lockdown via feasible generalized least squares fixed effect. Their results show that lockdown is effective in reducing the number of new cases, and it can keep 20 days[13]. Hien Lau et al. 's study focused on the lockdown period in Wuhan, during which the increase rate of cases decreased[14]. But Billy J Quilty found that airport screening is unlikely to detect a sufficient proportion of 2019-nCoV infected travelers[15]. In addition, some scholars believe that containment policies are not sustainable policies, and long-term use would seriously affect the economy and normal production and life order[9]. What are the effects of containment policies in the face of the long-term epidemic and constant variation of COVID-19? Thus, it was hypothesized that:

H1: Containment measures are negatively correlated with COVID-19 cases

Mobility is the public's response to the containment policies and the severity of the containment policies. Data of Google Mobility can effectively reflect the implementation of containment policies[16–19]. Many countries use movement restrictions as part of epidemic response[18]. Jose Maria Martin Moreno et al. studied the relationship among Vaccinations, Mobility, and COVID-19 Transmission. The study highlights the significance of mobility in realizing the effectiveness of COVID-19 vaccines[16]. Chenjing Fan's study believed that Migration may be the primary reason for the long-distance transmission of the disease, and proposed Containment policies[20]. The level of containment measures varies from country and period, with mandatory containment measures restricting access to people. And population movements may be exacerbated when containment policies are not in place or when there is a panic effect on the population about the virus[17,21,22]. In this paper, we study whether containment policies are related to mobility and how containment policies affect mobility. Thus, the following was hypothesized:

H2: Containment policies are negatively correlated with Mobility

In infectious diseases, mobility is strongly correlated with epidemic transmission[19,23]. When people move, they take contagious diseases with them and spread them. And since COVID-19 is spread through respiratory droplets and indirect contact, the reduction of mobility and contact reduction can reduce the effective reproduction rate (R_t) and control the disease epidemic. The achievement of R_t<1 is necessary to stop the spread of infectious diseases[24,25].In most studies, mobility is mostly used as a moderating variable[13,15,16]. Through modeling, Jayson S. Jia et al. found that mobility had a greater impact on COVID-19 spread in Hubei province, but a weaker impact outside Hubei Province[26]. In addition, mobility is considered to be an important factor leading to long-distance infection and prone to cluster outbreaks, which is also an important factor to be paid attention to in the long-term response to COVID-19[27,28]. Thus, the following was hypothesized:

H3: Mobility is positively correlated with COVID-19 cases

Figure 1 represents the research framework of this study. The novelty of this study is not only the systematic analysis of COVID-19 Containment policies, but also conducted an empirical study on the relationship among Containment policies, Mobility, and COVID-19 cases by constructing SEM

Figure 1 Research framework

3 Methods

3.1 Variables and Sources

In this article, we acquire the data on containment policies from Oxford COVID-19 Government Response Tracker (https://github.com/OxCGRT/covid-policy-tracker). According to Oxford COVID-19 Government Response Tracker, the study divided containment policies into the following categories: school closing, workplace closing, cancel public events, restrictions on gathering size, close public transport, stay-at-home requirement, and restrictions on international travel and assigns a value of 0-5 according to their severity. The mobility data at the country level is collected from Community Mobility Reports provided by Google（https://www.google.com/covid19/mobility/）. The Google Community Mobility Report reports population mobility data for six locations: retail and recreation, grocery and pharmacy, residential, transit stations, parks, and workplaces. In this work, mobility has changed compared to baseline days (the median value for the 5 weeks from January 3 to February 6, 2020). Data on COVID-19 cases are from Coronavirus Resource Centre at Johns Hopkins University (https://coronavirus.jhu.edu/?from=groupmessage). Thus, we collected data on Containment policies, Mobility, and COVID-19 cases in Chile, Singapore, South Korea and Israel from May 1, 2020, to April 30, 2022. Then, we take a set of data every six days and obtain a total of 488 sets of data.

3.2 Structural Equation Modeling

SEM was used to measure the causal relationships between latent variable constructs. It was run by using AMOS 24. This study considered using SEM in constructing a model of the impact of Containment policies – Mobility - COVID-19 cases.

4 Results

4.1 National trend of COVID-19 pandemic

As shown in Figure 2, overall, Trends of containment policies in four countries show an overall decline and phase fluctuations, which is generally consistent with the timing of the mutant strain in countries. And the total data in Chile is higher than in three other countries, especially in the early period of COVID-19. Chile closed public places and workplaces for a long time, canceling events, limited transportation, keep closing schools until the sanitary conditions allow a gradual return. Singapore's trend is relatively smooth. The changes in containment policies are small and return to the original state after a phased increase. Workplace closing and international travel controls remain largely unchanged. In the beginning, South Korea's containment policies were at a low level, and only school closing and international travel controls measures were taken. And public transport has never been shut down. South Korea only retained international travel controls after April 18, 2022. Israel's trend fluctuates greatly, showing a trend of sharp increase and sharp decline. The policy changes come from three policy changes: cancel public events, stay at home requirements, and restrictions on internal movement.

As shown in Figure 3, T1 to T6 are mobility data of places in retail and recreation, grocery and pharmacy, residential, transit stations, parks, and workplaces. For T1-retail and recreation, for most of the time, all four countries were below the baseline, showing an overall upward trend. But Chile in December 2021 and South Korea in June and December 2021 is above the baseline. For T2-grocery and pharmacy, there are much differences among four countries. For T3-residential, Chile, Singapore and the early period of Israel were higher than baseline, and in others has no obvious change compared with baseline. For T4-transit stations, others are below the baseline, except for Chile which is above the baseline after October 2021. For T5-parks, there are two trends. In Chile and Singapore, the trend of T5 is lower than baseline. However, in South Korea and Israel, trends are wild fluctuation and great higher than baseline, especially in South Korea. And the trend of T6-workplaces is similar as T4.

As shown in Figure 4, the rank of total cases in South Korea, Israel, Chile, and Singapore. For total cases per million n, Chile is 185,226.106 cases per million, Singapore is 218,800.43 cases per million, South Korea is 336,723.26 cases per million, Israel is 438,715.32 cases per million.

Figure 2 Trend of containment policies

Figure 3 Trend of mobility in Chile, Singapore, South Korea, and Israel (compared to baseline days -the median value for the 5 weeks from January 3 to February 6, 2020)

Figure 4 Total cases of COVID-19

4.2 Structural Equation Modeling

In this study, the Person correlation analysis was used to examine the relationship between latent variables used within the research scope, and the results were presented in Table 1. A significant correlation was observed among the three ($P<0.001$). There was a negative correlation between containment policies and mobility ($r = -0.662$, $P=0.00<0.001$) and COVID-19 cases ($r = -0.276$, $P=0.00<0.001$). There was a positive correlation between mobility and COVID-19 cases ($r = 0.176$, $P=0.00<0.001$). The two variables that were found to have a higher relationship level than other variables in the study were containment policies related to mobility. The relationship between these two variables was seen to be positive and moderate ($r = -0.662$, $P=0.00<0.001$). Furthermore, the weakest positive relationship between the variables was found between mobility and COVID-19 cases ($r = 0.176$, $P=0.00<0.001$).

Table 1 Correlation values between scales.

Before building the SEM, we tested the measurement models. After model modification, mobility and COVID-19 cases retained 3 factors respectively, which was exact identification, while containment policies retained 4 factors, which showed excellent fitting levels ($\chi^2/SD=1.78$, GFI=0.99, AGFI=0.98, NFI=0.99, RMSEA=0.04, CFI=0.99)[29].

In this stage, the impact of containment policies, mobility, and COVID-19 cases was investigated through SEM. Whether or not the measurement models were validated was then analyzed with Chi-square , χ^2/SD, GFI, AGFI, NFI, RMSEA, and CFI fit indices.

In the testing of the final model, the paths between the variables and the model were found to be significant at the 0.001 level. The fit indices of the hypothetical model were calculated as $\chi2/SD = 9.26$. Moreover, it was determined to have acceptable values of GFI = 0.91, AGFI = 0.84, NFI = 0.92, RMSEA = 0.13, and CFI = 0.93. These values reveal that the fit indices of the model can be considered as either good or within acceptable limits. The final SEM model is presented in Figure 5.

Figure 5 Final SEM model in this study

Moreover, **Error! Reference source not found.** presents the variance values, standard error, P, and standardized regression coefficients explained in the model regarding direct affection. After correction, all paths pass the significance test.

Table 2 Revised model path analysis results

The standardized regression coefficient between containment policies and mobility was found to be -0.84. This value indicates that there is a negative correlation between them. Moreover, containment policies are a strong influence factor on mobility. This result confirms the first hypothesis of the study (H1: Containment measures are negatively correlated with COVID-19 cases). The standardized regression coefficient between mobility and COVID-19 cases was found to be -0.29, which is a weak negative correlation. In other words, the regression weight for mobility in the prediction of COVID-19 cases is significantly different from zero at the 0.01 level. This result is inconsistent with the third hypothesis of the study (H3: Mobility is positively correlated with COVID-19 cases). The standardized regression coefficient between containment policies and COVID-19 cases was found to be -0.45. This result indicated that there was a moderate negative correlation between containment policies and COVID-19 cases found. This result confirms the second hypothesis of the study (H2: Containment policies are negatively correlated with Mobility).

5 Discussion

This study describes the Containment policies, Mobility, and COVID-19 cases in Chile, Singapore, South Korea and Israel in response to COVID-19. Chile, Israel and Singapore adopted containment strategies that focused on closure policies. Chile strictly managed population management and border closures. Israel focused on entry control, and Singapore adopted a regular blockade. In contrast, South Korea adopted a mitigation strategy, consistently refraining from a large-scale closure policy and focusing on vaccines and severe cases.

In addition, SEM of Containment policies, Mobility, and COVID-19 cases was used to test and analyze the proposed hypotheses. In COVID-19, Containment policies, Mobility, and COVID-19 cases were significantly and negatively related to each other. This paper discusses the three previously proposed hypotheses and provides targeted recommendations for responding to COVID-19.

5.1 National Containment policies, and mobility

In response to COVID-19, four countries have adopted different containment policies. mobility reflects the extent to which people are implementing policies and is reflected in COVID-19 case data. In this study, Chile, Israel and Singapore adopted containment strategies, focusing on the effect of lockdown measures and social restriction policies, which used lockdown to block epidemic spread. South Korea has adopted a mitigation strategy that focuses less on lockdown and more on vaccination and severe case management.

In the early stages of COVID-19, Chile attached importance to containment policies and focused on population management and border closing. Home quarantine was mandatory when Chile announced into "national disaster". In the global push for vaccination, Chile has seized the opportunity to accelerate vaccination far faster than any other country in the Americas[1,30]. Since Chile began mass vaccination in February 2021, mobility and COVID-19 cases have increased. Some academics have suggested that the rapid and effective vaccination campaign gave the Chilean government and people a false sense of security, lifting closure measures too early and causing too many people to traveling[2,31].

Like Chile, Israel is a vaccination star[8]. Israel is very sensitive to the use of containment policies, that is, policies are very variable and change with COVID-19. Israel has also seen the biggest change in blockade policy among the four countries. Among the containment policies, Israel has focused on entry control measures. Since Israel is a small country, most arrivals go through its only international airport, making entry control measures easier to implement[32]. Due to the rapid change of containment policies, Israel used Traffic Light Model to show the epidemic level in the region, so that the public could learn about it in time. However, the epidemic began to increase rapidly in 2022. On March 1, 2022, Israel announced the full opening of its borders, leading to an increase in COVID-19 cases.

Singapore responded quickly to COVID-19, preventing imported cases through a strict border policy. In the face of cluster outbreaks, Singapore promptly took lockdown measures to block the epidemic[33]. Although Singapore's containment policies have not changed much, they are much lower than those of the other three countries. Its mobility, except residential, is largely below the baseline. Even after Singapore's containment policies, mobility did not surge rapidly but steadily and slowly increased. This shows that the Singaporean people have a clear understanding of COVID-19. In practice, the regular lockdown measures are appropriate for Singapore[4].

South Korea has implemented a mitigation strategy in response to COVID-19. The severity of the lockdown policy remained at a low level and there was not any large-scale lockdown. For containment policy, South Korea mainly maintained school closing and international travel controls. In the early stages of COVID-19, South Korea responded to COVID-19 well, with COVID-19 cases at a low level. In addition, South Korea has set up drive-through nucleic acid testing sites and adopted an aggressive testing strategy to identify COVID-19 patients[34]. The turning point of COVID-19 in South Korea came in 2022. The omicron epidemic came as South Korea relaxed quarantine measures, easing border controls and pushing home quarantine policies. Polls in South Korea show that only a minority support strict lockdown policies, while majority support easing them, and there were gatherings for people infected with COVID-19. In this case, South Korea has further eased containment policies, and the daily COVID-19 cases became the highest in the world.

5.2 SEM model of Containment policies, mobility, and COVID-19 cases

Through the testing and revision of the model, the study found that there was a significant negative relationship among Containment policies, Mobility, and COVID-19 cases. In addition, the model shows that mobility and COVID-19 cases contradict the hypothesis. The results of the final SEM model are explained here. In the final SEM model, containment policies retain school closing, workplace closing, close public transport, and stay-at-home requirement: all of the four factors are policies to limit outgoings. In mobility, the three factors of the data of retail and recreation, grocery and pharmacy, and parks were retained, showing different trends in the four countries. COVID-19 cases retain the three factors of total cases, new cases, and new cases per million, which not only retain the overall case indicators but also pay attention to changing trends and national population data.

The results of this study point out that, first, there is a strong negative correlation between containment policies and COVID-19 cases, that is, COVID-19 cases decrease as the severity of containment policies increases. In response to the sudden COVID-19, many countries began to implement travel restrictions and border prevention and control policies, which are also effective ways to reduce COVID-19 cases entering the country[15,35]. Among containment policies included in the final model, the effect of the stay-at-home requirement (C6) on containment policies was the most significant, with factor loading reaching 0.93 under normalization. The stay-at-home requirement policy includes curfew, home isolation, banned for unessential activities, etc., which is also the most changed policy among containment policies of the four countries. Its audience is all citizens, which is also one of the important policies that require whole citizen[36,37]. The school closing, workplace closing and close public transport policies are all closed policies targeted at specific regions. However, COVID-19 is still in a long-term trend, and prolonged containment policies harm social and economic development[38]. However, we cannot deny the effect of containment policies on controlling COVID-19. Under such circumstances, the country should take appropriate containment policies following the trend of COVID-19, and implement relaxed containment policies that are easy to implement when COVID-19 enters into the normal period, so that COVID-19 prevention and control and economic development should be carried out simultaneously. This requires real-time monitoring and analysis of COVID-19 situation at home and abroad, and timely adjustment of the severity of policies.

Secondly, there is a moderate negative correlation between containment policies and mobility, that is, mobility decreases with the increase in the severity of containment policies. In the early stage of COVID-19, when the pathogenicity, transmission ways, mortality, and other characteristics of virus are not clear, there is a certain fear of COVID-19, and people tend to obey the policy arrangements and reduce mobility. And poor people are more vulnerable to COVID-19[39,40]. Mobility reflects the influence of the stay-at-home requirement policy through T3-Residential. The residential mobility in Chile and Singapore are both above the baseline, which shows that they implement strict stay-at-home requirement policies. Strong containment policies can effectively reduce mobility. Research by Matan Yechezkel also points out that in Israel closure policies have had a marked effect on mobility, especially the elderly [41]. And people's perceptions of epidemic risk also play a role in their response behavior. The more people perceive a higher epidemic risk, the more they tend to take protective measures. By 2021, when some countries began to downplay COVID-19, reduce the stringency of containment policies, and accelerate the resumption of work and production, the population's perception of the epidemic risk began to shift. Response behaviors showed by mobility have also changed, as evidenced by increased mobility in public places. The government should strictly review the publicity of COVID-19 and policies, and enhance public education, which enable the citizen to consciously implement the containment policy and reduce mobility.5

The last but not least, there was a weak negative correlation between mobility and COVID-19 cases, that is the number of COVID-19 cases decreased with increased mobility. This is contrary to our hypothesis H3. Yun Li's study suggests that mobility may not always directly affect COVID-19 trends[42]. For this reason, this study identifies a significant change in mobility of some countries after 2021. In Korea and Israel, park mobility figures remain high and much higher than at-home mobility. Stepping into the Omicron epidemic, the proportion of asymptomatic infections increases, and combined with the immune escape nature of the omicron variant, it is difficult to detect the virus with a single nucleic acid test[43,44]. The population perceives itself to be asymptomatic and delays or even does not seek medical care, which may lack case data but is exacerbated by population mobility. In addition, in the person correlation test, mobility and COVID-19 cases were positively correlated. In the person correlation, the data on mobility included data from public places and also from residential; however, the SEM screened 3 factors. We believe this may be the reason for the contradictory paths of person correlation and the SEM.

6 Conclusion

The study used the SEM to analyze the impact of Containment policy and Mobility on COVID-19 cases in Chile, Singapore, South Korea and Israel. Chile, Israel and Singapore adopted containment strategies, focusing on the effect of containment policies. South Korea adopted a mitigation strategy that focuses less on containment policies and more on vaccination and severe case management. In COVID-19, there is a significant negative relationship among Containment policies, Mobility, and COVID-19 cases.

To control the COVID-19 and slow down the increase of COVID-19 cases, countries can increase the stringency of containment policies when COVID-19 epidemic is more severe. Thus, countries can take measures from the following three aspects: strengthen the risk monitoring, and keep abreast of the COVID-19 risk; adjust closure measures in time and reduce mobility; and strengthen public education on COVID-19 prevention to motivate citizen to consciously adhere to preventive measures.

Ethics of Approval and Consent to Participate: This study did not involve ethical issues.

Patient and Public Involvement statement: No patient and public were involved in this analysis.

Consent for Publication: Not applicable.

Availability of data and material: The datasets analyzed during the current study are available in Oxford COVID-19 Government Response Tracker (https://github.com/OxCGRT/covid-policy-tracker), Google (https://www.google.com/covid19/mobility/), Johns Hopkins University (https://coronavirus.jhu.edu/?from=groupmessage).

Competing Interests: The authors have no conflicts of interest to declare.

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Figure 1

Figure 1 Research framework

Figure 1 Research framework

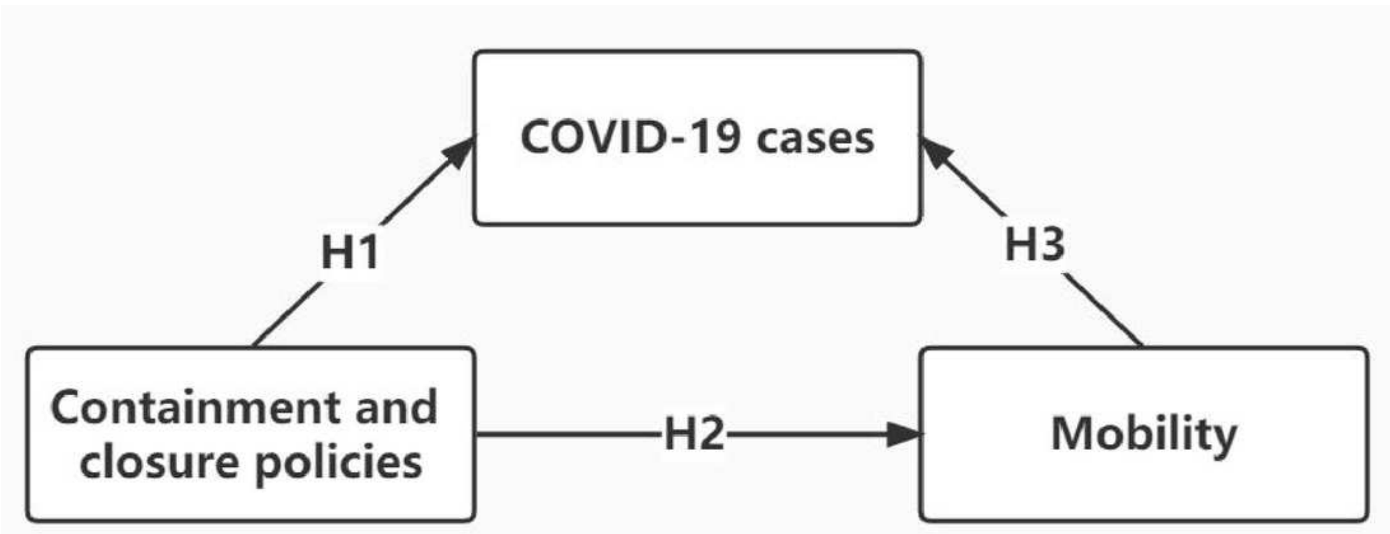

Figure 2

Figure 2 Trend of containment policies

Figure 2 Trend of containment policies

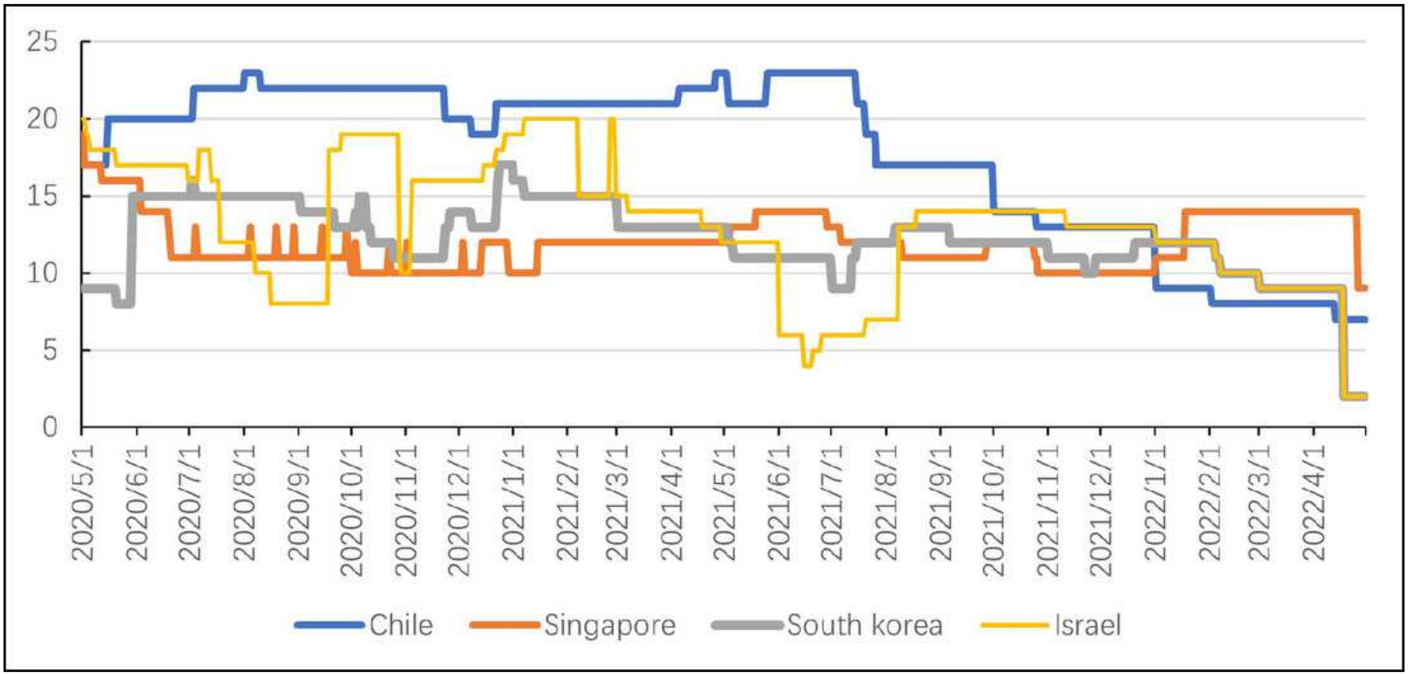

Figure 3

Figure 3 Trend of mobility in Chile, Singapore, South Korea, and Israel (compared to baseline days -the median value for the 5 weeks from January 3 to February 6, 2020)

Figure 3 Trend of mobility in Chile, Singapore, South Korea, and Israel (compared to baseline days -the median value for the 5 weeks from January 3 to February 6, 2020)

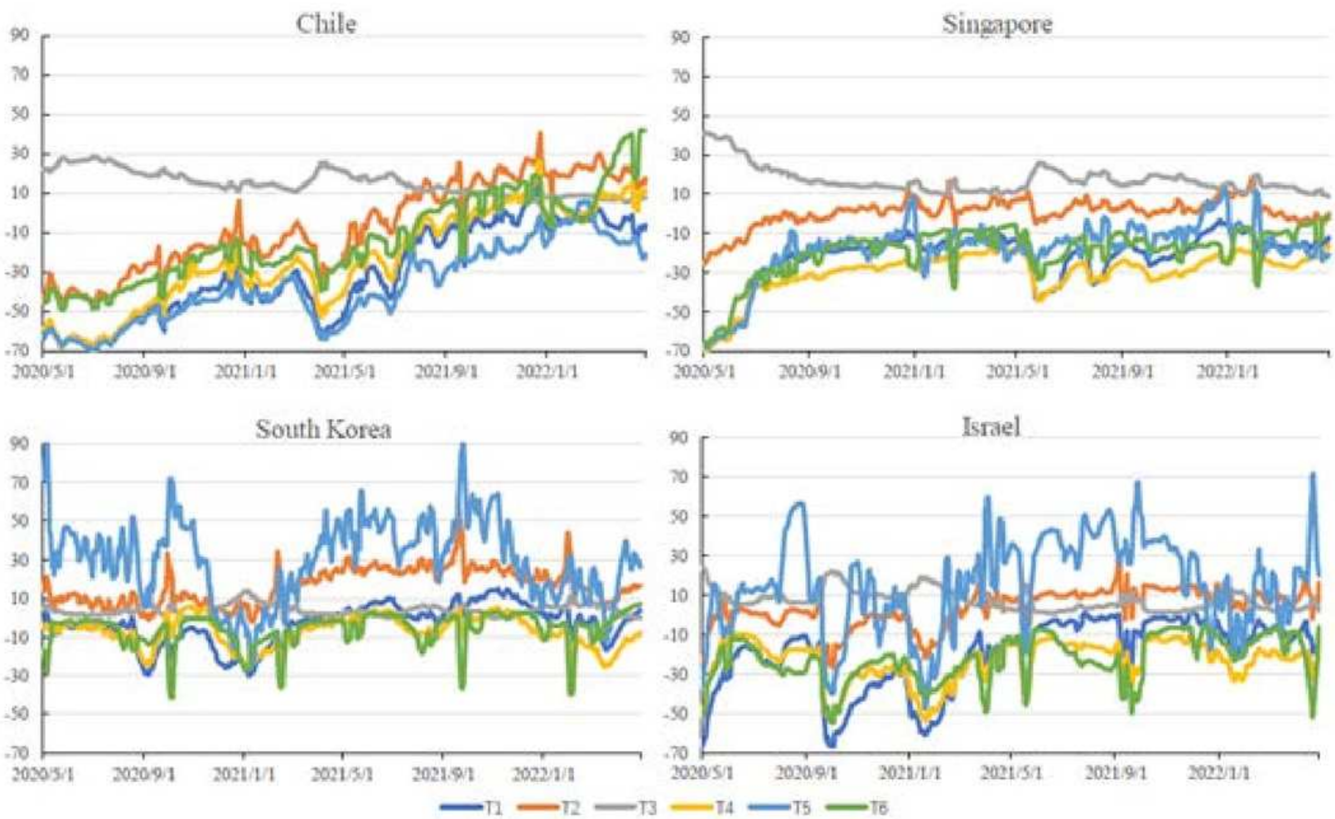

Figure 4

Figure 4 Total cases of COVID-19

Figure 4 Total cases of COVID-19

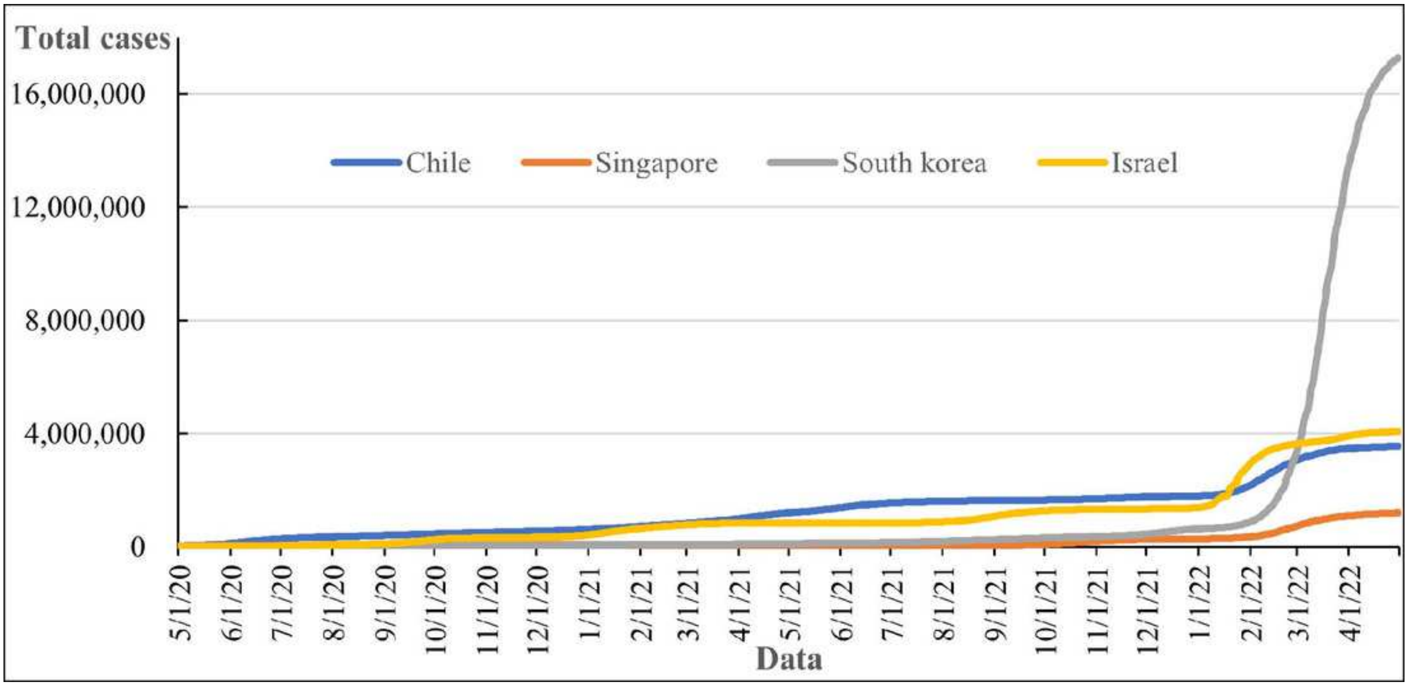

Figure 5

Figure 5 Final SEM model in this study

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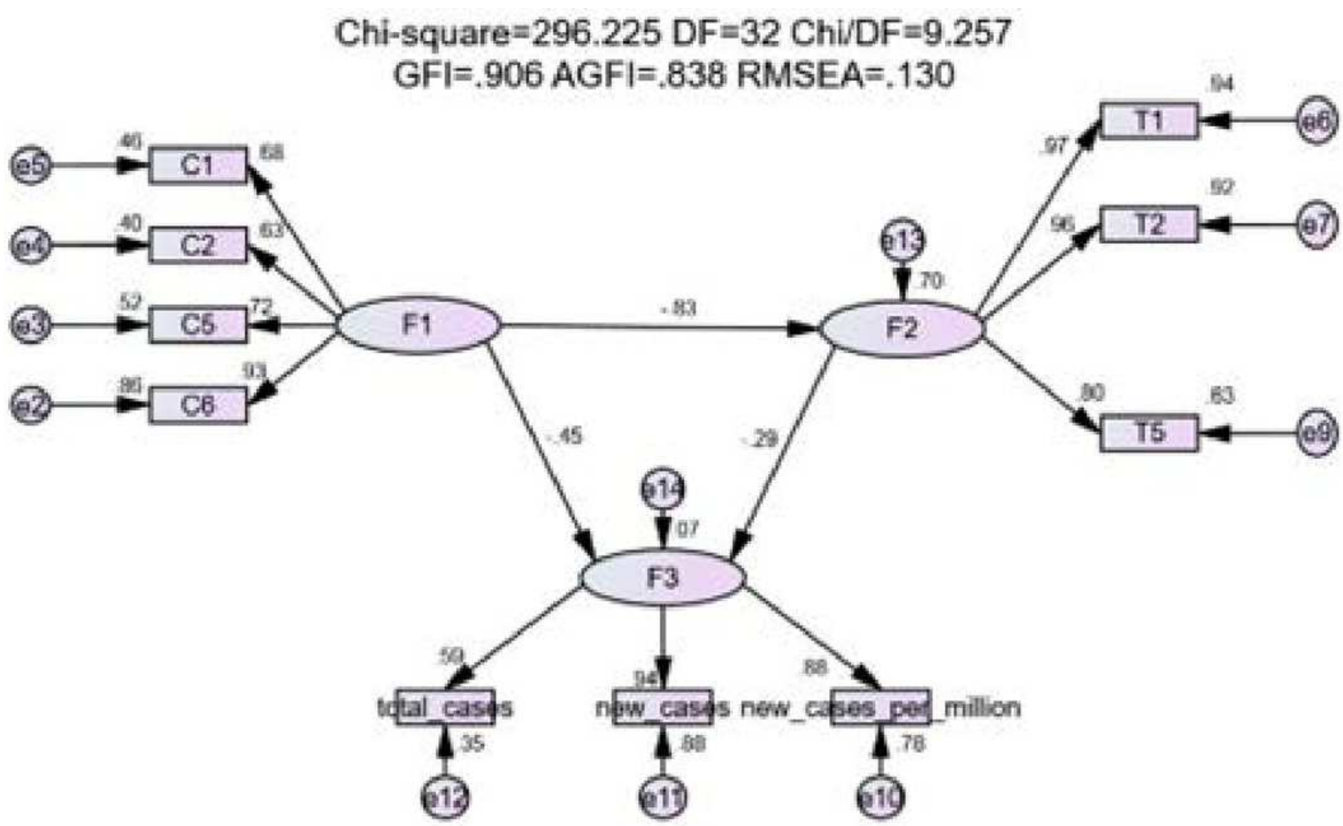

Table 1(on next page)

Table 1 Correlation values between scales.

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Scale	Containment policies	Mobility	COVID-19 cases
Containment policies	1	-0.66**	-0.28**
Mobility		1	0.18**
COVID-19 cases			1

***P< 0.001

Table 2(on next page)

Table 2 Revised model path analysis results

Table 2 Revised model path analysis results

Table 1 Revised model path analysis results

Path		Unstd.	Std.	S.E.	P
F2	F1	-25.49	-0.84	1.60	***
F3	F2	-17696.80	-0.29	6248.70	0.005
F3	F1	-831755.49	-0.45	203669.52	***
F1	C1	1	0.68	0.09	***
	C2	0.76	0.63	0.05	***
	C5	0.71	0.72	0.06	***
	C6	1.56	0.93		
F2	T1	1	0.97		
	T2	0.81	0.96	0.02	***
	T5	1.40	0.80	0.05	***
F3	B1	1	0.60		
	B2	0.04	0.94	0.01	***
	B4	0.01	0.88	0.00	***

***P< 0.001