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# Effects of non-pharmaceutical interventions against COVID-19: A cross-country analysis

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## Abstract

Prolonging non-pharmaceutical interventions (NPIs) used in the control of pandemics can cause a devastating effect on the overall economic and social welfare levels. Therefore, policymakers are facing a difficult duty in terms of implementing economically and socially sustainable and acceptable measures. The aim of this study is to investigate the effectiveness of NPIs implemented to control the COVID-19 pandemic. To this end, eight NPI measures were analysed, and their effects on the number of cases were investigated for France, Spain, China, and South Korea. In the study, the treatment effect of these mechanisms on the daily increase rate of the total number of cases during a certain period was analysed by using logarithmic linear regression with a dummy variables model. The findings indicate that the measures are effective against the spread of the pandemic at different levels. The findings also suggest that the most effective measure in decreasing the number of cases is workplace closure. An analysis comparing the effectiveness of countrywide measures and regional measures shows that school closing is the most effective measure to decrease the number of cases when implemented countrywide as opposed to regional implementation.

KEYWORDS
cross-country analysis, COVID-19 pandemic, logarithmic linear regression, non-pharmaceutical interventions

## 1 | INTRODUCTION

On 31 December 2019, the World Health Organization's (WHO) Country Office in China provided information on cases of pneumonia of unknown aetiology detected in Wuhan City, Hubei province, China.[1] Identified as a new coronavirus on 7 January 2020 and referred to as coronavirus disease 2019 (COVID-19) in the WHO's 23rd situation report,[2] the virus is in the agenda of all countries as the most important issue of the world today.

In fact, the world had previously met coronaviruses such as acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV). Although SARS-CoV, seen for the first time in China in 2002, caused worldwide concern, the number of infected people did not exceed 10,000 and the reports stated that the disease was seen in a total of 37 countries,[3] affecting China, Hong Kong and Taiwan the most.[4] Nevertheless, the SARS-CoV pandemic had a cost in 2003 at least as high as the Asian financial crisis and caused a much greater economic shock than expected considering its effect on health.[3] Similarly, the number of people infected with MERS-CoV in 2012 was limited to 3,000, and the virus was reported to have been seen in a total of 27 countries.[5] South Korea was the country with the highest incidence of MERS-CoV cases, excluding Saudi Arabia.[6] Throughout these pandemics, governments recommended paying attention to handwashing, mask usage and physical distance.[6] WHO published recommendations for individuals travelling to high-risk cities in order to reduce the international spread of SARS-CoV[7] and described the points to be taken into consideration by travellers to the Middle East because of MERS-CoV.[8]

Although the world has experience with coronaviruses, the pandemic that broke out in China spread uncontrollably to Asia, Europe, North America, and the Middle East and was confirmed in 213 countries and regions.[9] The causes of this dramatic spread are considered to be the fact that Wuhan is a connection point for China and that the emergence of the pandemic coincided with the Chinese New Year. In addition, it is claimed that the inadequacy of transparency of the Chinese Ministry of Health also contributed to the spread.[10] Starting locally but becoming a global fight, the pandemic has stirred up the whole world. WHO declared COVID-19 a health emergency of international concern on 30 January 2020, and on March 11, WHO's Director-General characterized COVID-19 as a pandemic.[11] As of 5 January 2021, the total number of confirmed cases was 86,248,818 and the number of deaths was 1,863,858.[9]

At the beginning of the pandemic, the absence of a medicine or vaccine[12,13] led governments to direct their efforts for controlling the pandemic to non-pharmaceutical interventions (NPIs).[14,15] Although the interventions were more strictly implemented in the Hubei region,[16] each country implemented NPIs at different levels and varieties, and at different time periods.[17] NPIs can be broadly categorized as: (i) personal protective measures such as hand hygiene and mask usage, (ii) environmental measures such as surface and object cleaning, (iii) social distance measures such as school closing and isolation of sick individuals, and (iv) travel-related measures such as travel restrictions and border closing.[18] NPIs are implemented for three main outcomes, namely to delay the timing of the peak to buy time for necessary preparations in the healthcare system, to reduce the size of the peak so that the healthcare system is not overwhelmed, and to spread the pandemic over a longer time period to create a potential for a vaccine.[19] Even though there are still uncertainties about how the timing, duration, and intensity of NPIs can reduce the effect of COVID-19,[20] the interventions contribute to containing the pandemic at different levels. However, prolonging these implementations can cause devastating effects on the overall economic and social welfare levels.[17,21] It is clear that COVID-19 has caused a medical shock for many economies.[22] For example, in the US, before the pandemic the unemployment rate reached in February 2020 the lowest level in the last 67 years [23] However, in only five weeks following the outbreak of the pandemic 26 million US citizens applying for unemployment benefits.[24] Although there are exceptions such as China, in its 'World Economic Outlook' report published on 14 April 2020, the International Monetary Fund stated that the world economy was projected to contract more sharply than the 2008–2009 financial crisis, as the quarantine and social distance measures taken due to the coronavirus pandemic brought economies to a standstill.[25] Considering all these, countries have a responsibility for implementing economically and socially sustainable interventions that can provide the most powerful and quickest effects against the spread of the pandemic.[16,14] This has speeded up studies on the effect of different NPIs on COVID-19.[13–17,20,26–29]

This study investigates the effectiveness of NPIs related to the containment and closure mechanisms implemented to control COVID-19, using Spain, France, China, and South Korea as examples. Containment and closure mechanisms are measures that prevent/restrict the physical interaction between individuals. These are defined as: C1-School closing, C2-Workplace closing, C3-Cancel public events, C4-Restrictions on gatherings, C5-Close public transport, C6-Stay at-home requirements, C7-Restrictions on internal movement, and C8-International travel controls.[30] In this study, the treatment effect of these mechanisms on the daily increase rate of the total number of cases during a certain time period was analysed by using a logarithmic linear (log-lin) regression with dummy variables (LLRDV) model. The findings contribute to a better understanding of which NPIs are more effective, offering clues for creating an effective instrument against future new waves.

## 2 | DATA AND METHOD

To specify the effects of the measures taken by countries for mitigating the spread of COVID-19, this study focuses on France, Spain, China, and South Korea. In order to determine the daily increase rate of the total cases (DIRTC) of COVID-19 of the $i^{th}$ country during the period between the date when the first case was recorded and 1 June 2020, we compute the growth factor (b), which is refers DIRTC, for the $i^{th}$ country by using a simple exponential growth function for each day. For this purpose, we collect data for each country from the Our World in Data website, which uses data of daily cases of COVID-19 from the WHO situation reports.[31]

In addition, we gather information about the measures taken by each country from the Oxford University Blavatnik School of Government (OUBSG) website,[30] which classifies the measures (containment and closure mechanisms) as indicators and publishes these indicators in a systematic cross-national and time series structure in order to understand how governments respond to the period of the outbreak's spread. OUBSG entitles this project the Oxford COVID-19 Government Response Tracker (OxCGRT).

OxCGRT issues proper information on the containment and closure mechanisms (CCM) indicators (C1-C8) of government response (*C1-School closing*, *C2-Workplace closing*, *C3-Cancel public events*, *C4-Restrictions on gatherings*, *C5-Close public transport*, *C6-Stay-at-home requirements*, *C7-Restrictions on internal movement*, *and C8-International travel controls*). These indicators are recorded as an ordinal scale with categorical variables. Additionally, the C1 to C7 indicators are classified as either *targeted* (implemented solely within a geographically region) or *general* (applied to a whole jurisdiction) (OUBSG, 2020). The total cases (TC), daily cases (DC) and DIRTC (b) of the countries investigated are demonstrated in Figure 1.

In order to investigate and evaluate the impacts of the measures (identified as CCM indicators) taken by the government of these countries against the spread of the COVID-19 outbreak, we assume the CCM indicators (categorical variables) as dummy explanatory variables. These which are the key component for event study whose target is to specify whether a particular event influences some outcome[32] and also useful tools for researchers to clarify something that implements only to a single observation in a regression consisting of time series data.[33] They are also commonly used in fields such as sociology, psychology, education, and market research.[34]

To achieve our goal of evaluating the *treatment effect* of the mechanisms emerged from policy intervention, we propose LLRDV models in which the indicators (categorical variables) are described as dummy variables and are generally chosen to compare the group of interest with a reference group. Since the regression coefficients represent the mean differences between interested and reference groups,[35,36] it can be a useful tool for this model to find and compare the effect of each indicator level separately. Although some indicators are described in three categories (i.e., 0: no measures, 1: recommend cancelling, and 2: require cancelling), only two categories (i.e., 1: no measures and 2: recommend closing) are recorded for the period of the analysis related to these countries. Thus, we determine the dummy variables bearing in mind the categories defined in the interested period. In order to

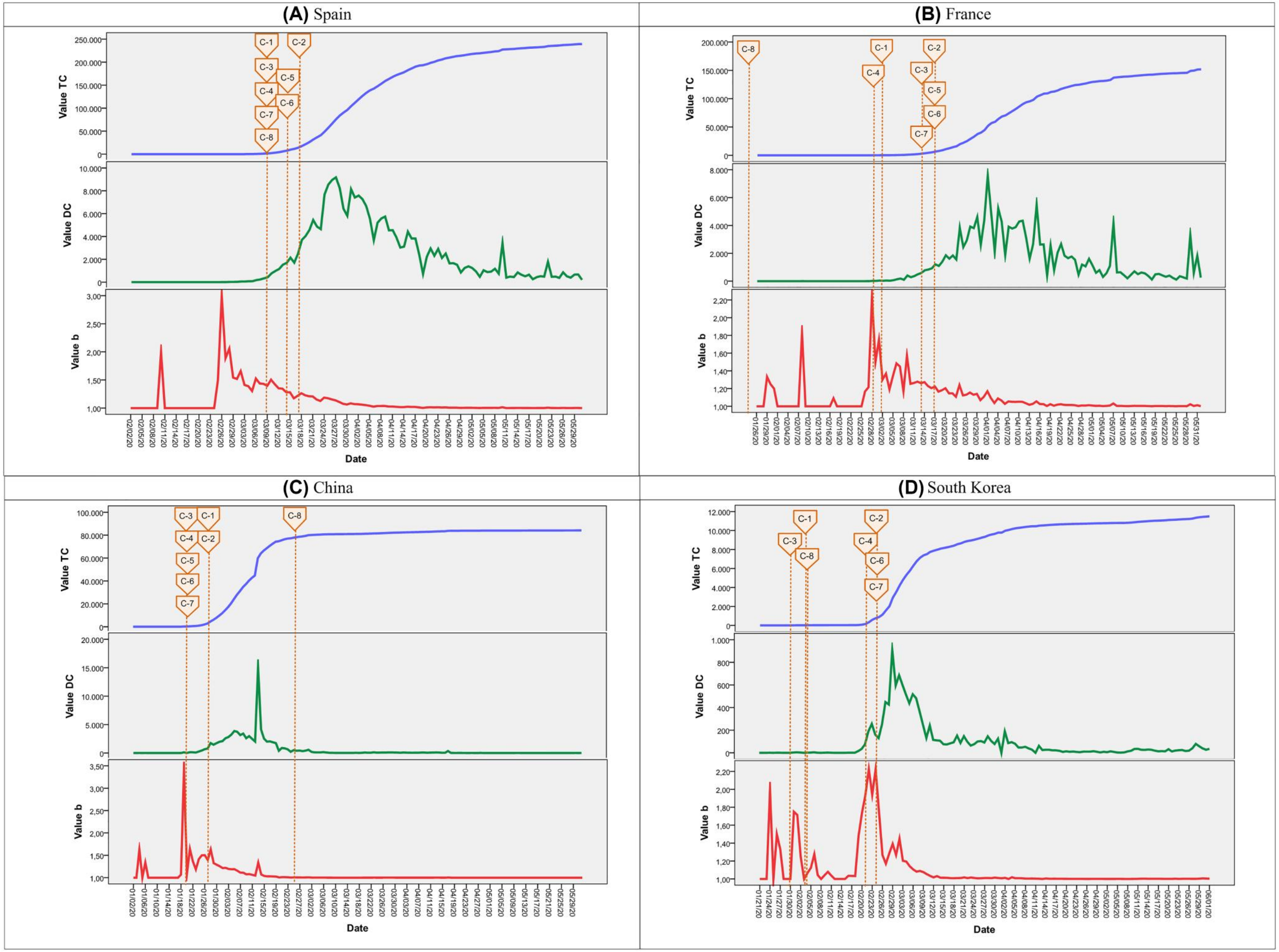



**FIGURE 1** Total case (TC), daily case (DC) and daily increase rate of total cases (DIRTC [b]) of countries [Colour figure can be viewed at wileyonlinelibrary.com]

compute the real impacts of the CCM indicators on the DIRTC of the i$^{th}$ country accurately, a 7-day lag is added to the time series model as proposed by Banholzer et al. and Chen and Qiu.[21,37] Consequently, the LLRDV models are represented by Equations 1–2.

For C1–C8 CCM indicators with a 7-day lag:

$$\text{lnDIRTC}_{it} = \beta_{ij0} + \sum_{j=1}^{k-1} \beta_{ij} D_{ijt-7} + u_{it} \tag{1}$$

For C1–C7 CCM indicators that are recorded as geographic scopes, we also assume a 7-day lag:

$$\text{lnDIRTC}_{it} = \beta_{ij0} + \sum_{j=1}^{k-1} \beta_{ij} GD_{ijt-7} + u_{it} \tag{2}$$

$\text{lnDIRTC}_{it}$: natural logarithm of DIRTC of the i$^{th}$ country related to the t$^{th}$ day

**$B_{ij0}$**: intercept that expresses the mean of the category recorded as 0 for the j$^{th}$ indicator related to the i$^{th}$ country
**K**: number of categories of the independent variable
**$\beta_{ij}$**: dummy regression coefficient of the j$^{th}$ indicator of the i$^{th}$ country
**$D_{ijt}$**: dummy variable of the j$^{th}$ indicator of the i$^{th}$ country related to the t$^{th}$ day
**$GD_{ijt}$**: dummy variable of the j$^{th}$ indicator (general scope) of the i$^{th}$ country related to the t$^{th}$ day
**$u_{it}$**: error (residual) term

## 3 | RESULTS OF ANALYSIS

To examine the impacts of the measures taken by countries against the spread of the COVID-19 outbreak, the dummy definitions of the regression models are illustrated in Supplementary Appendix A, and the summary of the results of the LLRDV is presented in Supplementary Appendix B. The mean effects of the CCM indicators belong to four countries on the reduction of the spread of COVID-19 are demonstrated in Figure 2.

The results in Figure 2 show that C2 (Workplace closing) indicator has the most effective CCM indicator ($\bar{X}$ = 53.71%, LB = 31.38%, and UB = 76.04% at 95% confidence interval) for mitigating the DIRTC. C6 (Stay at home requirements) is the second most effective CCM indicator ($\bar{X}$ = 38.28%, LB = 22.53%, and UB = 54.03% at 95% confidence interval), and C4 (Restrictions on gatherings) is the third most effective CCM indicator ($\bar{X}$ = 35.68%, LB = 19.80%, and UB = 51.56% at 95% confidence interval) for reducing the DIRTC. The mean effects of the CCM indicators (C1–C7) belong to four countries as geographic scope on the mitigation of the DIRTC are illustrated in Figure 3.

From the results obtained from Figure 3, it can be concluded that the mean effects of most of the CCM indicators have overlapping confidence intervals. C1 (School closing) has the most effective CCM indicator ($\bar{X}$ = 23.01%, LB = 15.26%, and UB = 30.76% at 95% confidence interval) as geographic scope for mitigating the DIRTC. C2 (Workplace closing) is the second most effective CCM indicator ($\bar{X}$ = 20.63%, LB = 12.79%, and UB = 28.48% at 95% confidence interval), and C3 (Cancel public events) is the third most effective CCM indicator ($\bar{X}$ = 20.12%, LB = 12.40%, and UB = 27.83% at 95% confidence interval) for reducing the DIRTC.

In order to compare the mean impacts of the CCM indicators on the DIRTC of each country separately, according to different indicator levels ($D_i$ = 1, $D_{i2}$ = 1, $D_{i3}$ = 1, etc.) with reference categories $D_i$, $D_{i2}$, $D_{i3}$ = 0 (no measure), or for geographic scope ($DG_i$ = 1 (general), $DG_i$ = 0 (targeted)), the LLRDV model is performed for the C1–C8 and C1-C-7 (geographic scope) CCM indicators for each country. The impact values of the CCM indicators of related to the reduction of the DIRTC for each country are illustrated in Figure 4.

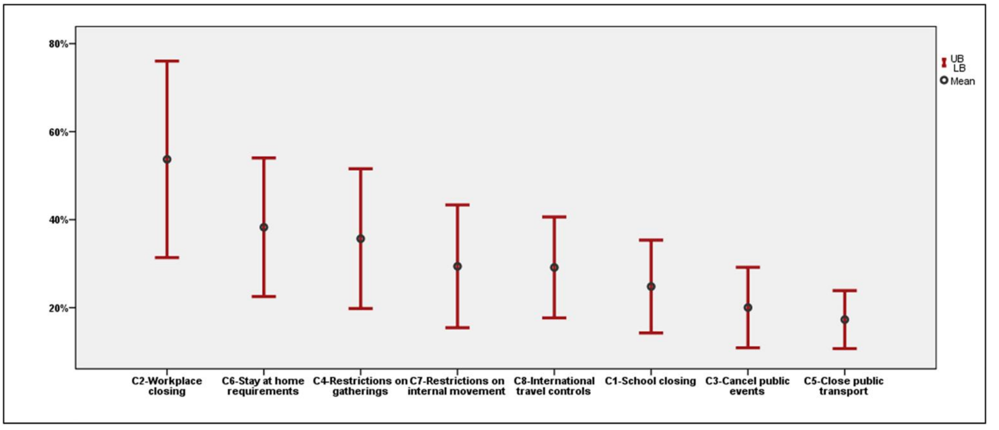



**FIGURE 2** The mean effect of containment and closure mechanism (CCM) Indicators on reducing the daily increase rate of total cases (DIRTC) [Colour figure can be viewed at wileyonlinelibrary.com]

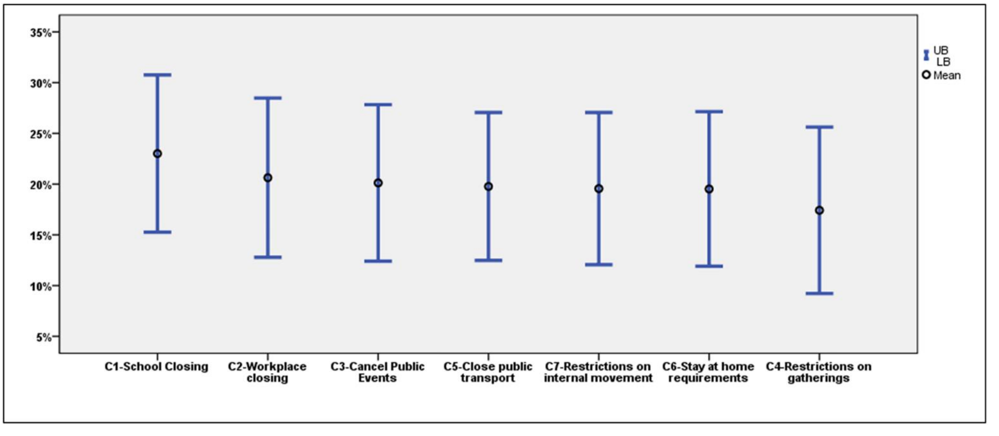
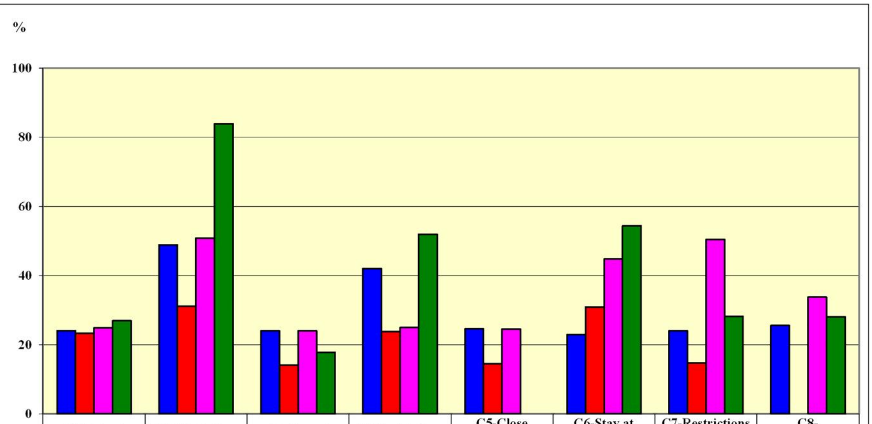



**FIGURE 3** The mean effect of containment and closure mechanism (CCM) indicators (geographic scope) on reducing the daily increase rate of total cases (DIRTC) [Colour figure can be viewed at wileyonlinelibrary.com]

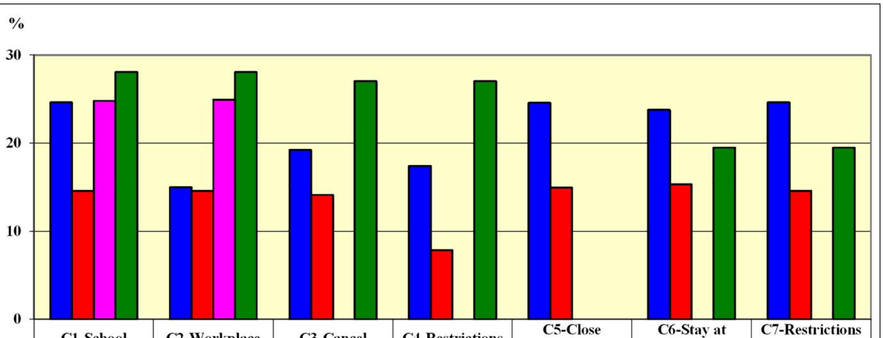
From the findings in Figure 4, it can be deduced that most of the measures taken by countries exert various impacts for reducing the DIRTC. South Korea has the highest impact values for the C1, C2, C4, and C6 CCM indicators (26.92%, 83.93%, 51.97%, and 54.42% respectively), China has the highest effect values for the C3, C7, and C8 CCM indicators (24.07%, 50.53%, and 33.79% successively) for mitigating the DIRTC. Overall, the CCM indicators of China and South Korea have higher impact values (mean of eight indicators: 41.62%, and 34.81% respectively) than Spain and France (mean of eight indicators: 29.54%, and 21.80% respectively) with regards to reducing the DIRTC. The impact values of the CCM indicators (geographic scope) related to the reduction of the DIRTC for each country are illustrated in Figure 5.

According to the results of the impact of the CCM indicators (geographic scope) on the reduction of the DIRTC, South Korea has also the highest impact values (C1: 28.06%, C2: 28.06%, C3: 27.02%, and C4: 27.02%) for




| | C1-School closing | C2-Workplace closing | C3-Cancel public events | C4-Restrictions on gatherings | C5-Close public transport | C6-Stay at home requirements | C7-Restrictions on internal movement | C8-International travel controls |
|---|---|---|---|---|---|---|---|---|
| Spain | 24.06 | 48.88 | 24.06 | 42.05 | 24.62 | 22.96 | 24.06 | 25.59 |
| France | 23.28 | 31.18 | 14.12 | 23.74 | 14.55 | 30.92 | 14.80 | NS |
| China | 24.95 | 50.85 | 24.07 | 24.97 | 24.52 | 44.82 | 50.53 | 33.79 |
| South Korea | 26.92 | 83.93 | 17.85 | 51.97 | NS | 54.42 | 28.21 | 28.06 |

**FIGURE 4** Impact of containment and closure mechanism (CCM) indicator on reducing of the daily increase rate of total cases (DIRTC) related to countries [Colour figure can be viewed at wileyonlinelibrary.com]




| | C1-School closing | C2-Workplace closing | C3-Cancel public events | C4-Restrictions on gatherings | C5-Close public transport | C6-Stay at home requirements | C7-Restrictions on internal movement |
|---|---|---|---|---|---|---|---|
| Spain | 24.62 | 14.98 | 19.20 | 17.40 | 24.59 | 23.77 | 24.62 |
| France | 14.57 | 14.55 | 14.12 | 7.83 | 14.95 | 15.31 | 14.57 |
| China | 24.81 | 24.95 | NDRSM | NDRSM | NDRSM | NDRSM | NDRSM |
| South Korea | 28.06 | 28.06 | 27.02 | 27.02 | NDRSM | 19.49 | 19.49 |

**FIGURE 5** Impact of containment and closure mechanism (CCM) indicator (geographic scope) on reducing of the daily increase rate of total cases (DIRTC) related to countries [Colour figure can be viewed at wileyonlinelibrary.com]

mitigating the DIRTC on four indicators. Spain has the highest effect values for the C5, C6, and C7 CCM indicators (24.59%, 23.77%, 24.62% and respectively) for reducing the DIRTC on four indicators.

## 4 | DISCUSSION

Containment and closure mechanisms as NPIs are implemented at different degrees/levels by countries and regions affected by the COVID-19 pandemic. Considering the economic and social burdens it has brought, it is clear how important it is for all countries to determine the effectiveness of these interventions. This study investigated the effectiveness of NPIs in Spain, France, China, and South Korea, which have different social, cultural, and economic structures and are located on different continents, on the fight against the pandemic by using a data set covering a certain time period.

The findings obtained indicate that the measures are effective against the spread of the pandemic at different levels. The findings suggest that the most effective measure in decreasing the number of cases is workplace closing. This is followed by stay-at-home requirements and restrictions on gatherings. It seems that the least effective measure in decreasing the number of cases is closure of public transport. These results bear similarities with the various findings of the study by Banzolher et al. in which they compared the effectiveness of NPIs for 20 countries. 21 Two studies show that bans on gatherings cause a significant reduction in the number of cases. However, two other studies suggest that school closings and cancelation of public events provide a less distinct decrease in the number of cases. Chen and Qiu's study on nine countries demonstrate that centralized quarantine is the most effective NPI, followed by lockdown, school closing and mask wearing.[37] This research shows that school closing is less effective in the decrease of the number of cases than other measures, which is similar to the results in our study. Davies et al. investigated various scenarios for the COVID-19 infection and control in the UK and found that moderate interventions such as a 12-week school closing, self-isolation and protection of elderly groups were not adequate to take the pandemic under control and avoid exceeding the available intensive care unit capacity, even when a combination of these measures were used.[20] Again, the result that school closings were not effective against the spread of the pandemic shows a similarity with our study. When these studies are evaluated together, it can be said that the prominent result is that school closings do not have a high-level effect on reducing the number of cases. To increase the effectiveness of all measures, social network-based strategies could be a good complementary tool.[38]

However, according to the analysis results that compared the effectiveness of countrywide measures and regional measures, school closing is the measure that provides the most decrease in the number of cases when implemented on a national level compared to regional implementation. Considering all measures, it can be concluded that countrywide implementations are more effective than regional implementations.

According to the findings obtained by comparing the effectiveness of the measures across countries, the country where school closing, workplace closing, restrictions on gatherings and stay-at-home requirements decreased the number of cases the most is South Korea. By implementing these measures effectively and utilizing widespread free testing and public information provided by mobile technology, South Korea was able to hold the number of patients at a certain level. The country where measures regarding cancelation of public events, restrictions on internal movement and international travel controls decreased the daily number of cases the most is China. Kramer et al. studied the effects of the measures taken in China for preventing human mobility and found that the speed of spread of the pandemic decreased considerably with the help of the implemented measures.[39] Another study stated that quarantining the city of Wuhan, together with the measures later implemented by other cities, significantly contributed to the reduction of the total number of cases outside Wuhan. According to the simulation results of this study, if the city of Wuhan had not been quarantined on 23 January 2020, the number of COVID-19 cases could have been 52.64% higher in 16 cities within Hubei province, apart from Wuhan, and 64.81% higher in 347 cities in provinces outside Hubei.[40] These findings coincide with our analysis results that indicate that China is the most successful country in the measures for restricting human mobility such as cancelation of public events, restrictions on internal movement and international travel controls. Overall, it can be concluded that the measures taken decreased the number of cases more in South Korea and China than in France and Spain. As the main reason for this, it can be said that China and South Korea's social and cultural structures along with China's experience with SARS-CoV and South Korea's experience with MERS-CoV, which are other types of coronavirus, helped with the effectiveness of the implemented measures. In addition, the differences between the effectiveness of the measures across countries could be the result of human behaviour. As stated by Coroiu, Moran, Campbell, and Geller adherence to measures vary depending on motivation or individual reasons.[41]

In conclusion, the findings obtained have the potential to make various contributions to the field of practice. Firstly, the findings present to policymakers the evaluation of the effectiveness of containment and closure mechanisms defined as NPIs, based on empirical evidence. Thus, it is possible to compare the social and economic burdens brought by these containment and closure mechanisms and their effectiveness. Moreover, it enables the identification of the effects caused by these mechanisms in countries with different social and cultural structures. In addition, the comparison of the effectiveness created by the general and regional implementation of measures can be used by policymakers as an important decision criterion. Such a comparison also offers the opportunity to contribute to the decision-making process as to which measures are to be implemented on a regional level and which measures are to be implemented countrywide.

This study treats the level at which each of the NPIs partially reduces the number of cases. As the process regarding the COVID-19 pandemic has not yet ended, completeness of case data may vary over time and across countries. Compliance to the measures may also vary over time and across countries. Therefore, the analyses to be carried out as the process proceeds can yield different results. In addition, since some countries have made no progress or are just at the start of the pandemic process, some analyses may show that the effects of these measures do not provide significant outcomes.

Since the relevant data set about the pandemic will be more comprehensive in future studies, new findings can be obtained. Worldwide analyses or analyses for different countries can be done by increasing the number of countries in the data set. In this study, the effect of the measures was analysed by using the 7-day lag value widely accepted in the literature. In subsequent studies, analyses can be carried out to determine the effect of delay values by taking different values for the delay time. In addition to the partial effect of the measures, their effect on situations can be presented. Moreover, the scope of the analysis can be extended by also including, in addition to the eight indicators, variables with daily data such as the daily test number.

## 5 | CONCLUSION

The results of this study highlight several important points. First, the measures are effective against the spread of the pandemic at different levels. Workplace is the most effective measure. This is followed by stay-at-home requirements and restrictions on gatherings. On the other hand, closure of public transport is the least effective measure in decreasing the number of cases. Second, there are differences between effectiveness of countrywide measures and regional measures. School closing provides the most decrease in the number of cases when implemented on a countrywide compared to regional. Considering all measures, the countrywide implementations are more effective than regional implementations. Finally, the differences between the effectiveness of the measures across countries could be the result of human behaviour. Therefore, social dimensions should be considered in implementing measures. Social network-based strategies could be effective in complementing of these measures.

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### CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

### ETHICS STATEMENT

No ethical approval was obtained because secondary and open access data were used.

## DATA AVAILABILITY STATEMENT

All of the data were obtained from the Oxford University Blavatnik School of Government (OUBSG). The data about the measures taken by France, Spain, China, and South Korea are extracted and can be reached from: figshare.com DOI: doi.org/10.6084/m9.figshare.13642637.v1

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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