Effect of Physical Contact Limitations and Social Spacing Practices in Mitigating Epidemiologic Spread: Analyzing COVID-19 Government Containment Strategies in the Arab World

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Abstract

As health systems around the world struggle to respond to the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a novel specie of the coronavirus family accountable for the coronavirus disease 2019 (COVID-19), the reality of this pandemic framed several important global environmental health issues into sharp focus. It is becoming increasingly evident that environmental and ecological variables play a significant role in dictating the scenario in which the spread of COVID-19 takes place. These variables interact with pre-existing ecological circumstances and tend to trigger the magnitude of population health response and disease control that usually ensues. Ongoing attempts to understand the proliferation of SARS-CoV-2 include research on the role of the built environment in human behavior that influences COVID-19 infection rates and disease severity; such as business closures, suspension of educational institutions, imposed government curfews, etc. Hence, as the international community begins to enact an expansive scale of preventive strategies in reaction to COVID-19 – albeit varying in degree or extent of prevention and response time – nevertheless; the preservation of life became the primary mandate for many national governments, whereby several interventions to bring down COVID-19 related infections and deaths were promulgated on a country-level scale. Such interventions, among others, included nationwide lockdowns, domestic and international travel restrictions, quarantine and isolation for the infected, public interaction limitations, and donning of personal protective equipment. Given the various interventions implemented in the State of Kuwait since the first confirmed cases of COVID-19 were registered in February 2020, it is essential to evaluate the policy responses taken by the government to determine their efficacy in reducing the loss of lives and mitigating the pandemic in the country.

Keywords: COVID-19 control; Government response; Infectious disease restrictions; Physical distancing; Viral transmission.

1. Background

The coronavirus disease 2019 (COVID-19) infection heralded a surreal change in previously conventional approaches to public health emergencies. This change must encompass the simultaneous consideration of both communicable and non-communicable diseases, while also accounting for the unique requirements of vulnerable groups of individuals, the basal causes of disease, the growing prevalence of non-human to human transfer of diseases, and the communal, financial, and ecological factors pertinent to equally communicable as well as non-communicable diseases.

Notwithstanding the mounting evidence that establishes a correlation between non-communicable diseases (NCDs) and communicable diseases (CDs), these two domains are frequently influenced by perpendicular schemes that operate with distinct resource channels, analogous organizations, and inadequately harmonized guidelines, as per the National Academies of Sciences, Engineering, and Medicine (2019). The present disjointed governing structures, establishments, and protocols in the healthcare sector and elsewhere remain insufficient in tackling many health-related problems concurrently (Smith and Lee, 2017).

Research gleaned from the COVID-19 outbreak and past pandemics have demonstrated that isolated government institutions and other state entities acting within their own silos tend to encounter significant difficulties in mobilizing committed stakeholders and key decision-makers and will likely struggle to garner sufficient public support when operating unilaterally. It is important to note that collaborative efforts can be coordinated solely by implementing multisectoral and multistakeholder frameworks of governance structures. This necessitates the involvement of a considerable amount of stakeholder groups reflecting multiple viewpoints and interests spanning a wide range of different sectors, as the National Academy of Medicine highlighted in 2016.

COVID-19 imparted each nation state with unprecedented obstacles in governance. The Middle East and North Africa (MENA) region, habitually yet falsely depicted as monolithic, shows extraordinary variance among the nations compromising it, in terms of socioeconomic, doctrinal, civic, and topographical aspects. With regards to COVID-19, government-mandated response measures within the primitive phases of the global outbreak have set the stage for how the viral outbreak evolved in the region, and such differences among Arab MENA countries grow noticeable as they touch on state official, authoritative rules and courses of action to suppress disease infection, countering particular local actualities on the ground.

While certain dynamic forces and observable undercurrents mutually exist across the geographic region, yet, it remains compulsory to take a closer look and analyze COVID-19 response policies implemented in neighboring countries to learn how certain government efforts have worked for some and not so much for others. For example, the six Gulf Cooperation Council (GCC) member states (Kuwait, Bahrain, Qatar, Oman, Saudi Arabia, and the United Arab Emirates) possess much more advantageous developmental indicators of gross domestic product (GDP) per capita, well-regarded structures of governance, and a robust macroeconomic climate. However, migrant workers encounter social disparities that render them more susceptible to viral infections, ultimately making them further prone to developing diseases (World Economic Forum, 2018). Moreover, it is worth noting that the Gulf Cooperation Council (GCC) exhibits one of the most pronounced incidences of COVID-19 cases per million individuals globally, as reported by Worldometer in 2020. In contrast, it is worth noting that countries such as Lebanon and Jordan reflect a comparatively less robust fiscal landscape, coupled with a substantial influx of war-displaced people seeking refuge (United Nations High Commissioner for Refugees [UNHCR], 2020). The COVID-19 containment attempts in places such as Iraq and the Occupied Palestinian Territories are characterized by enduring political turmoil and inadequate state/government institutional structures (West Bank and Gaza) (Bowen, 2020).

This regional empirical study on the effect of physical dissociation and degree of contact spacing initiatives in suppressing disease-causing contagions within populations found in fourteen Arab MENA countries/territories (Egypt, Kuwait, Bahrain, Iraq, Qatar, United Arab Emirates (UAE), Saudi Arabia, Lebanon, Jordan, Morocco, Occupied Palestinian Territories (West Bank and Gaza), Oman, Algeria, and Tunisia) has yielded valuable insights that can potentially be developed further and referenced for future health emergencies in the region. Although earlier epidemic modeling investigations have postulated the indispensable role of implementing physical separation strategies in social spaces to effectively mitigate dissemination of COVID-19 virus, however, it is worth noting that only a limited number of empirical studies have substantiated these assertions, and scarcely any of them have exclusively relied upon data derived from Arab Middle Eastern and North African countries/territories. The present study endeavors to assess the efficacy of a range of social spacing and contact limiting initiatives in mitigating pathogen spread within each respective country, employing the time-varying reproduction number as a system of evaluation measurement.; a time rate measure in epidemiology estimating the projected figure of consequent cases generated as a result of respectively confirmed cases of infected individuals in a given population (herein denoted Rt – where t is time), thus indicating the degree of spread or contagion dispersal while also used as a valuable metric in viral transmission dynamics for quantifying transmissibility of infections associated with a physical dimension (time) and therefore reported in units of time.

2. Introduction

As of May 31, 2020, the worldwide effects of COVID-19 has been observed in a total of 5.93 million individuals with a consequential loss of over 367,000 lives, thus marking the initial rise of a deadly pandemic (World Health Organization [WHO], 2020). In light of the unavailability of efficacious therapeutics or vaccines during that period, the implementation of containment strategies hinged upon the ability to regulate viral spread via "non-pharmaceutical interventions or NPIs" (Kissler *et al.*, 2020). New research results suggest that the clinical efficacy of case separation and traceability of contacts approaches can be augmented by incorporating measures to distance individuals physically in social spheres (Chu *et al*., 2020; Kucharski et al., 2020). Authorities and health officials across the globe have exercised a range of social spacing tools, exhibiting differing degrees of strictness and promptness in their implementation. The physical spacing patterns encompass a series of preventive actions, including the shutdown of academic institutes and workplaces, elimination of public gatherings and community events, limitations on large crowding, the cessation of public transit, the implementation of stay-at-home directives, constraints on within border freedom of movements, and the enforcement of regulations on beyond border external travel. Given social and economic interference resulting from these policies, it is imperative to quantitatively assess their influence on the propagation of diseases in order to derive valuable insights from any oversights made in the initial stages of the pandemic and to inform policymakers moving forward, which have primarily been relying on infectious disease modeling reports (Ferguson *et al.*, 2020; Prem *et al.*, 2020). As the number of positive individuals continues to amass, we have now reached a point where it is feasible to utilize empirical data obtained from on-the-ground observations to corroborate the theory-based model estimations regarding the efficacy of government interventions.

The objective of this study is to examine the effects of measures of physical separation on transmitted viruses, with a particular emphasis on quantifying the changes in the time-varying reproduction number (Rt). The R*t* signifies the anticipated quantity of subsequent instances of disease that emerge from a single initial positive instance within a specified timeframe, when the epidemic curve has reached a normalized point. Values of R*t* that exceed one indicate a high probability of a persistent outbreak. Consequently, the primary objective of policy interventions and response strategies is to decrease the R*t* value to under one (1), thereby indicating that the outbreak is effectively managed.

3. Methodology

Physical separation and social spacing initiatives

The data pertaining to the application of physical separation policies in each country within the Arab MENA region, spanning from January 1, 2020, to May 28, 2020, was procured from the Oxford COVID-19 Government Response Tracker (OxCGRT). This comprehensive tracker diligently gathers pertinent information regarding various governmental policies, meticulously assigns a numerical score to gauge the strictness of these measures, and subsequently amalgamates the data into a standardized index. The Stringency Index (SI) serves as a comprehensive metric, possessing a numerical value ranging from 0 to 100. A greater index value signifies a heightened degree of severity. The influence of specific measures was further examined to which strategies have an ordinal scale of rigor and strength (Hale *et al.*, 2020):

School closures
Workplace closures
Cancellation of public events
Restrictions on the size of gatherings
Public transport closures
Stay-at-home orders
Limitations imposed upon the act of internal movements
Restrictions of traversing national borders for individuals engaging in international travel

Assessment of the real-time reproduction number

The point of disease propagation was standardized in order to mitigate the potential confounding influence of escalated caseload on infection dynamics. It is anticipated that the efficacy of interventions will vary when confronted with 10 cases as opposed to 1,000 cases. Consequently, a total of 100 cases were employed as the initial benchmark across all nations to signify the commencement of an outbreak (Hartfield and Alizon, 2013).

R*t* values for all Arab MENA states which have reported at least 100 cases as of May 28, 2020, were then estimated – leaving us with a total of fourteen countries/territories. The evaluation encompassed the entirety of the period commencing from the initial reported case up until the date of May 28th. This was achieved by employing a weekly sliding window approach derived from the methodologies established by Cori *et al.* in 2013. Using the Pan-American Health Organization (PAHO) and World Health Organization's (WHO) COVID-19 Estimator, the rate of COVID-19 transmission was estimated for each country using the quantity of confirmed positive cases on particular days according to the R package "EpiEstim" (Cori *et al.*, 2013, 2019; R Core Team, 2019). The interface by the WHO-PAHO is capable of generating evolving epidemiological curves, which depicts the number of single-point incidents over time (*t*). It estimates R (reproductive number) as a function of time t with 95% confidence intervals to help countries successfully monitor transmission rates and prescribe public policies addressing the COVID-19 pandemic. The method of computation employs sliding weekly windows, incorporating a parametric serial interval derived from a mean value of μsi = 4.8 and a standard deviation of σsi = 2.3; however, later studies suggest that SARS-CoV-2 may spread faster than SARS but slower than H1N1 (Setti and Voutilainen, 2020). Hence, for the purpose of calculating Rt, we incorporated the serial interval of COVID-19 as suggested by Nishiura *et al.* (2020), with a mean of 4.7 and a standard deviation (SD) of 2.9. Each day's confirmed positive case data reports were obtained from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

One of the salient characteristics inherent in the examination of R*t* as opposed to cumulative case numbers lies in its profound significance. It is worth noting that in the event that the proportion of unreported cases remains constant throughout the course of an outbreak, estimations of R*t* remain impervious to the deleterious effects of underreporting, as expounded upon by Thompson *et al.* in their seminal work published in 2019.

Regression model

Since countries would first implement then later relax physical distancing policies as a reactionary response to the pandemic, ascertaining causation from these policy initiatives to a modification in Rt is very challenging. To address any potential reverse causation, the country initiatives in place at the time of identification of the 100th positively confirmed case were thus examined. The variable "Rt" was subsequently monitored and recorded in a temporal manner for a duration of 14 consecutive days. The utilization of lagged measures serves the purpose of effectively controlling for the endogenous response that arises due to viral spread.

The dependent variable, Rt, was subjected to a regression analysis in order to examine its relationship with physical contact spacing measures and other covariates. The factors of control that were used in this study encompassed various factors. Firstly, the income level was measured using the logarithm of the Gross Domestic Product (GDP) per capita at current US dollars. Secondly, population density was taken into consideration by allowing the logarithm of the number of individuals per square kilometer. Thirdly, the age structure of the population was considered, specifically focusing on the proportion of individuals aged 65 years and above. To finish, temperature was factored in by examining the 14-day average temperature following the occurrence of the 100th case. The assumed influence of illness dissemination is attributed to various socioeconomic and environmental factors, as elucidated by Liu *et al.* (2020) and Qiu *et al.* (2020). Data on GDP per capita, population density, and the age structure of the population were obtained from the World Bank's World Development Indicators, while temperature data was collected from the Air Quality Open Data Platform and other online weather resources.

Lastly, to validate the robustness of the study results, the increase in the total sum of cases as a percentage seen across the 14 days since the date of the 100th case was employed as the dependent variable in our regression model. Additional evaluations using country-level mobility data from Google Community Mobility Trends Reports were conducted and studied further to show reality measures of physical distancing data and assess on-the-ground behavioral differences instead of country-mandated preventive orders. Regressions and statistical analyses were conducted in Stata 16.1 (StataCorp LLC).

4. Results

First, general assessments of the association between physical contact limitations/social spacing practices and Rt were made before evaluating the magnitude of association using regression models. Oxford's COVID-19 Government Response Tracker (OxCGRT) Stringency Index (SI) is a composite index of physical distancing measures that record the stringency of "lockdown style" mandates that predominantly limit population behavior (Hale *et al.*, 2020). Daily stringency values, or changes in stringency levels over time, can be measured from OxCGRT data reports and computed using total ordinal containment and closure policy indicators. Overall, according to Table 1, it seems that Rt (averaged over 2 weeks immediately after the 100th positive case was identified) among the fourteen Arab MENA countries/territories slightly differ, fluctuating according to the stringency level of physical and social distancing actions reported on the date that the 100th positive case was confirmed and identified. As can be visually determined in Figure 1 below:

On average, based on the negative downward sloping red line, countries with higher stringency levels on the date that the 100th positive case was confirmed and identified and who were implementing more stringent physical distancing measures/non-pharmaceutical interventions (NPIs) tended to show inferior Rt values;

None of the countries associated with an index of stringency below 80 could reduce their mean Rt to under one (1) by the 14 days that followed, as can be seen in Oman [SI=81.48, Rt

=0.97] – based on our estimates of its time-varying reproduction number using reported case data;

For the most part, countries with a stringency level above 80 and Rt below 1.5 on the date the 100th positive case was confirmed and identified have overall maintained the sum of total cases (dimensions of each depicted bubble) at a controllable stage (as of May 28).

Table 1. Estimated Time-Varying Reproduction Numbers (Rt) and Stringency Index on the Date that the 100th Positive Case was Confirmed and Identified

Country/Territory	SI	Estimated R*t*	Total cases as of May 28, 2020
Egypt	18.52	1.80	19,666
Kuwait	74.07	1.33	23,267
Bahrain	25.00	1.47	9,633
Iraq	77.78	1.58	5,135
Jordan	100.00	1.39	720
Lebanon	52.78	1.21	1,161
Qatar	30.56	1.44	48,947
UAE	45.37	1.15	31,969
KSA	68.52	1.51	78,541
Morocco	90.74	1.38	7,601
Palestine (West Bank & Gaza)	94.44	1.27	613
Oman	81.48	0.97	8,373
Algeria	36.11	1.86	8,857
Tunisia	87.96	1.51	1,051

Note. UAE=United Arab Emirates; KSA=Kingdom of Saudi Arabia; SI=Stringency Index (a composite index of physical distancing measures with a range of 0-100 calculated by the OxCGRT – larger values indicate higher stringency).

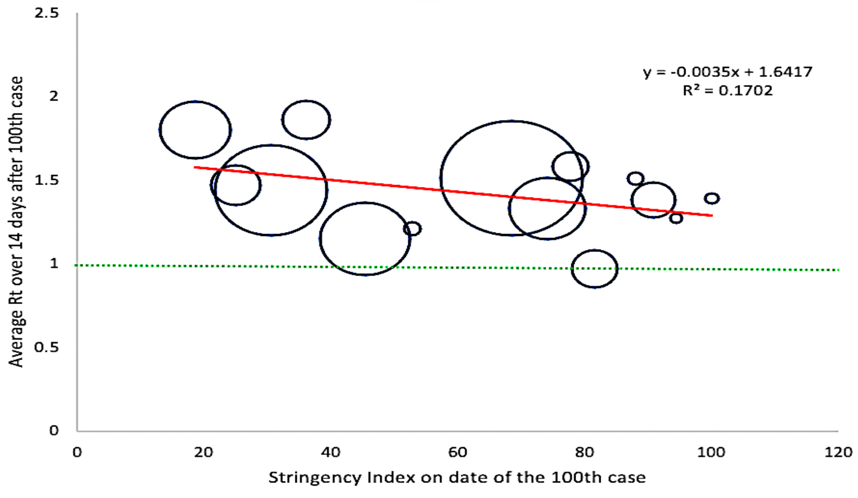

Figure 1.

Figure 2. Stringency Index of Physical Distancing Measures on the Date of the 100th Case and Average Reproduction Numbers in the Following Two Weeks. Note. The time-varying reproduction number (R*t*) is the expected number of secondary COVID-19 cases generated by a primary case at time t. The Stringency Index (SI) is a composite index of physical distancing measures with a range of 0-100 as calculated by the OxCGRT – larger values indicate higher stringency levels. Each bubble signifies a country, and the size of the bubble is proportional to the total number of reported cases as of May 28, 2020. The solid red line is the best linear fit of the relationship between the stringency level on the date of the 100th reported case and the average R*t* in the following two weeks. The dashed green line is the R*t* threshold, where a value below one suggests that a sustained outbreak is unlikely if measures remain in place.

A cursory look at the OxCGRT data helped establish the timeliness of government response policies by weighing the mean timing of operation for each social separation and physical spacing measure, as illustrated in Table 2. Reported government response policies show that, on average, some of the earliest implemented policy measures among our Arab MENA countries/territories were the restrictions on external, cross-border travel (roughly 11 calendar days prior to the discovery of primary COVID-19 individual case). Subsequently, during the initial phases of disease propagation, approximately one week following the discovery of the primary COVID-19 case, it appears that the first-line policy defenses in effect were the termination of public events and the closure of educational institutions. These actions were then succeeded by imposing limitations on the scale of mass gatherings and implementing more rigorous measures, such as the cording off of businesses, constraints on internal mobility, mandates to remain at home, and the cessation of public transit.

T**able 2**. Summary of Physical Distancing Measures and Average Timing of Implementation

Physical distancing measures	Average date of implementation	Average days after 1st case	Average days after 100th case
Restrictions on international travel	February 22, 2020	-10.8	-33.4
Cancelation of public events	March 11, 2020	8.3	-14.6
School closures	March 12, 2020	9.3	-13.5
Restrictions on the size of mass gatherings	March 17, 2020	13.8	-9.1
Workplace closures	March 17, 2020	14.9	-7.6
Restrictions on internal movement	March 19, 2020	16.6	-6.2
Stay-at-home orders	March 22, 2020	18.5	-5.0
Public transport closures	March 22, 2020	18.5	-4.0

Note. Calculations were based on OxCGRT data of 14 Arab MENA countries as of May 28, 2020 (Hale *et al*., 2020).

Since several measures were implemented, on average, within proximity of one another and because of the similar nature of certain NPIs, it can be challenging to correlate the noted alterations in Rt to a particular prevention policy. This problem of relating findings directly back to a specific initiative was eventually addressed by cluster combining – considering both the time government strategies of containment were first in effect and their correspondence to each other, as seen in Table 3. Three identifiably distinct data classifications of physical contact distancing and social spacing mandates are agreeable to further analysis:

1. Controls on transnational travel;
2. Limitations on crowd congregations;
3. Lockdown-type measures.

Table 3. Pairwise Correlation of Physical Contact Distancing and Social Spacing Initiatives

	C1	C2	C3	C4	C5	C6	C7	C8
C1_School closure	1.0000							
C2_Workplace closure	0.5520	1.0000						
C3_Cancel public events	0.7101	0.4774	1.0000					
C4_Size restriction on gathering	0.5433	0.4898	0.6171	1.0000				
C5_Public transport closure	0.4044	0.5343	0.4084	0.4550	1.0000			
C6_Stay-at-home order	0.4455	0.6350	0.4337	0.5488	0.6043	1.0000		
C7_Internal movement restriction	0.5027	0.5745	0.5330	0.5921	0.6331	0.6989	1.0000	
C8_International travel restriction	0.4754	0.3422	0.5022	0.4643	0.4510	0.4230	0.5212	1.0000

Note. Calculations were based on OxCGRT data of 14 Arab MENA countries as of May 28, 2020 (Hale *et al.*, 2020).

The force and aptness of implementation vary within each category, and the extensive scope of measures within these categories are highlighted below in Table 4. Based on a definition method described by Takagi (2020), country-specific physical distancing measures were regarded as introduced early in each country if the amount of calendar days from the time of policy implementation and the date of the 100th confirmed COVID-19 case is lower in quantity than the observed average at the time, otherwise, they are deemed to be introduced late into the pandemic. For example, according to our definition approach and by using OxCGRT data, Oman was the fastest-acting Arab MENA country to implement policies banning arrivals from some countries/regions (about 52 days before the date when its 100th positive case was confirmed and identified, paralleled to the overall average of approximately 31 days prior to the confirmed identification of the 100th positive case); whereas Egypt, on the other hand, noticeably had put external cross-border policies into effect late (roughly 5 days post its 100th positive case was confirmed and identified).

Table 4. Range and Timeliness of Physical Distancing Measures by Category

Measure	Level	Definition
Restrictions on international travel (TR)	0 – No measures 1 – Screening; late 2 – Screening; early 3 – Quarantine arrivals from high-risk countries; late 4 – Quarantine arrivals from high-risk countries; early 5 – Ban on arrivals from some countries; late 6 – Ban on arrivals from some countries; early 7 – Ban on all countries or total border closure; late 8 – Ban on all countries or total border closure; early	OxCGRT C8 = 0 OxCGRT C8 = 1; implemented late OxCGRT C8 = 1; implemented early OxCGRT C8 = 2; implemented late OxCGRT C8 = 2; implemented early OxCGRT C8 = 3; implemented late OxCGRT C8 = 3; implemented early OxCGRT C8 = 4; implemented late OxCGRT C8 = 4; implemented early
Restrictions on mass gatherings (MG)	0 – No measures 1 – Recommend canceling of public events; late 2 – Recommend canceling of public events; early 3 – Require canceling of public events & restrictions of gatherings above 10 ppl; late 4 – Require canceling of public events & restrictions of gathering above 10 ppl; early 5 – Require canceling of public events & restrictions on gatherings of 10 ppl or less; late 6 – Require canceling of public events & restrictions on gatherings of 10 ppl or less; early	OxCGRT C3 = 0 & C4 = 0 OxCGRT C3 = 1 & C4 = 0; implemented late OxCGRT C3 = 1 & C4 = 0; implemented early OxCGRT C3 = 2 & C4 = 1, 2 or 3; implemented late OxCGRT C3 = 2 & C4 = 1, 2 or 3; implemented early OxCGRT C3 = 2 & C4 = 4; implemented late OxCGRT C3 = 2 & C4 = 4; implemented early
Lockdown-type measures (LD)	0 – No measures 1 – Recommend workplace closure (or work from home), recommend not leaving home, or recommend not to travel between cities/towns; late 2 – Recommend workplace closure (or work from home), recommend not leaving home, or recommend not to travel between cities/towns; early 3 – Require closing for some work sectors or require not leaving home with exceptions for daily exercise, groceries, and essential trips; late	OxCGRT C2 = 0 & C6 = 0 & C7 = 0 OxCGRT C2 ≤ 1 & C6 ≤ 1 & C7 ≤ 1; implemented late OxCGRT C2 ≤ 1 & C6 ≤ 1 & C7 ≤ 1; implemented early OxCGRT C2 = 2 or C6 = 2; implemented late OxCGRT C2 = 2 or C6 = 2; implemented early OxCGRT C2 = 3 or C6 = 3 or C7 =

Measure	Level	Definition
	4 – Require closing for some work sectors or require not leaving home with exceptions for daily exercise, groceries, and essential trips; early 5 – Require closing of all but essential workplaces, require not leaving home with minimal exceptions or restrictions on internal movement; late 6 – Require closing of all but essential workplaces, require not leaving home with minimal exceptions or restrictions on internal movement; early	2; implemented late OxCGRT C2 = 3 or C6 = 3 or C7 = 2; implemented early

Note. Definitions applied using OxCGRT data (Hale *et al*., 2020). A measure is considered "early" if the number of days between the implementation date and date of the 100th case is less than the median and "late" otherwise.

The limitations of external border movement are exclusively predicated upon the OxCGRT's C8 indicator. The parameters imposed on mass gatherings are a confluence of the OxCGRT indicators C3, which relates to the termination of public events, and C4, pertaining to the declaration of size restrictions on gatherings. Ultimately, the combined application of lockdown form of policies involves the integration of OxCGRT's C2 (workplace closures), C6 (stay-at-home requirements), and C7 (restrictions on internal movement) indicators, as illustrated in Table 5. For example, in the case of lockdown-type measures, recommendations and government advisories on within border freedom of movement that had been operated by the time of the median quantity of days before the official day of the 100^{th} positive COVID-19 report came in is considered late and the least stringent indicators, whereas comprehensive shutdown policies with closures of all non-vital employment settings and quarantine-in-place decrees that were implemented in more than the median number of days before the 100^{th} case are considered early and the most stringent as shown in Table 6.

Table 5. Used Indicators and Adopted Coding Methodology of Containment and Closure Measures

ID	Name	Description	Measurement	Coding
C2	C2_Workplace closing	Record closings of workplaces	Ordinal scale	0 - no measures 1 - recommend closing (or recommend work from home) or all businesses open with alterations resulting in significant differences compared to non-Covid-19 operation 2 - require closing (or work from home) for some sectors or categories of workers 3 - require closing (or work from home) for all-but-essential workplaces (e.g., grocery stores, doctors) Blank - no data

ID	Name	Description	Measurement	Coding
	C2_Flag		Binary flag for geographic scope	0 - targeted 1- general Blank - no data
C3	C3_Cancel public events	Record canceling public events	Ordinal scale	0 - no measures 1 - recommend canceling 2 - require canceling Blank - no data
	C3_Flag		Binary flag for geographic scope	0 - targeted 1- general Blank - no data
C4	C4_Restrictions on gatherings	Record limits on gatherings	Ordinal scale	0 - no restrictions 1 - restrictions on very large gatherings (the limit is above 1000 people) 2 - restrictions on gatherings between 101-1000 people 3 - restrictions on gatherings between 11-100 people 4 - restrictions on gatherings of 10 people or less Blank - no data
	C4_Flag		Binary flag for geographic scope	0 - targeted 1- general Blank - no data
C6	C6_Stay at home requirements	Record orders to “shelter-in-place” and otherwise confine to the home	Ordinal scale	0 - no measures 1 - recommend not leaving house 2 - require not leaving house with exceptions for daily exercise, grocery shopping, and 'essential' trips 3 - require not leaving house with minimal exceptions (e.g., allowed to leave once a week, or only one person can leave at a time, etc.) Blank - no data
	C6_Flag		Binary flag for geographic scope	0 - targeted 1- general Blank - no data
C7	C7_Restrictions on internal movement	Record restrictions on internal movement between cities/regions	Ordinal scale	0 - no measures 1 - recommend not to travel between regions/cities 2 - internal movement restrictions in place Blank - no data

ID	Name	Description	Measurement	Coding
	C7_Flag		Binary flag for geographic scope	0 - targeted 1- general Blank - no data
C8	C8_International travel controls	Record restrictions on international travel * Note: this records policy for foreign travelers, not citizens)	Ordinal scale	0 - no restrictions 1 - screening arrivals 2 - quarantine arrivals from some or all regions 3 - ban arrivals from some regions 4 - ban on all regions or total border closure Blank - no data

Note. Five of the indicators (C2-C4, C6-C7) contain flags if, in case, they are "targeted" to a particular community or within-border region in the country (flag=0) or if initiatives in effect are considered "general" state policies that have been implemented widely across countries/territories as a whole (flag=1). An indicator with flag=0 is weighted less compares to flag=1 for computation of total stringency index values. Based on information and variable definitions obtained from the OxCGRT codebook v2.3.

Table 6. Stringency Levels and Timeliness of Physical Dissociation and Degree of Contact Spacing Initiatives by Country on Day 100th Positive Case was Confirmed and Identified

Country	TR	MG	LD	Date of 100th case
Egypt	0	0	3	March 16, 2020
Kuwait	7	5	3	March 14, 2020
Bahrain	1	0	0	March 10, 2020
Iraq	5	6	5	March 16, 2020
Jordan	7	5	6	March 24, 2020
Lebanon	8	1	4	March 17, 2020
Qatar	6	1	0	March 12, 2020
UAE	6	3	2	March 18, 2020
KSA	7	3	5	March 16, 2020
Morocco	7	4	6	March 23, 2020
Palestine (West Bank & Gaza)	7	6	6	March 30, 2020
Oman	8	6	6	March 27, 2020
Algeria	5	3	0	March 21, 2020
Tunisia	5	5	6	March 25, 2020

Note. UAE=United Arab Emirates; KSA=Kingdom of Saudi Arabia; TR=restrictions on international travel; MG=restrictions on mass gatherings; and LD=lockdown-type measures.

Also, the mechanism of how the average R*t* over the two weeks after the date the 100th positive case was confirmed and identified fluctuates with every physical dissociation and degree of contact spacing initiative has been evaluated. In general, earlier implementation and more stringent standards lower the R*t* value (based on a negative downward slope) denoted in Figure 2. For example, such as can be seen in Figure 2 that considers international travel restrictions, the cluster of countries with lower R*t* values below 1.5 had notably implemented an early banning on arrivals from other countries, or even executed a total closure of their borders. For mass gathering restrictions as depicted in Figure 3, R*t* values below one were only observed in Oman [Rt=0.97], which implemented early policies that required the cancelation of public events and controlled crowding of even ten people or under. It is quite intriguing to observe that, thus far, no nation has succeeded in reducing their Rt values to a level below 1.5 without resorting to the implementation of any form of restrictive measures akin to a lockdown. Overall, Arab MENA countries/territories do not appear to record fewer total cases of COVID-19 by May 28, 2020 (size of each bubble in Figure 4) – despite implementing earlier and more stringent physical dissociation and degree of contact spacing initiatives on the day the 100th positive case was confirmed and identified and mean R*t* value; the data is still unclear and inconsistent.

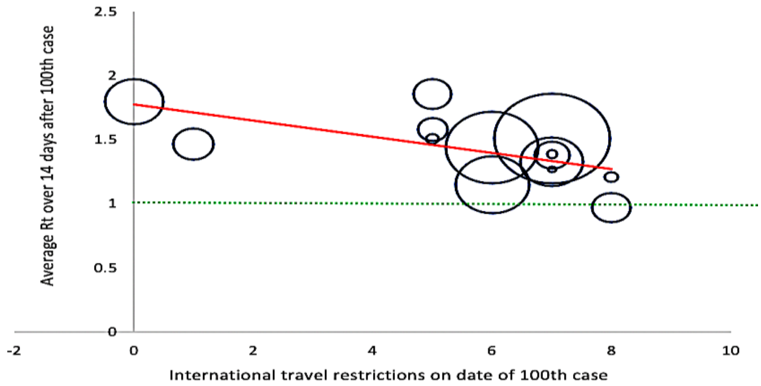

Figure 3

Figure 4 Restrictions on International Travel on Date of the 100th Case & Average Reproduction Numbers in the Following Two Weeks. *Note.* Rt = expected number of secondary cases generated by a primary case at time t. Please refer to Table 4 for details and specific measures on international travel restrictions.

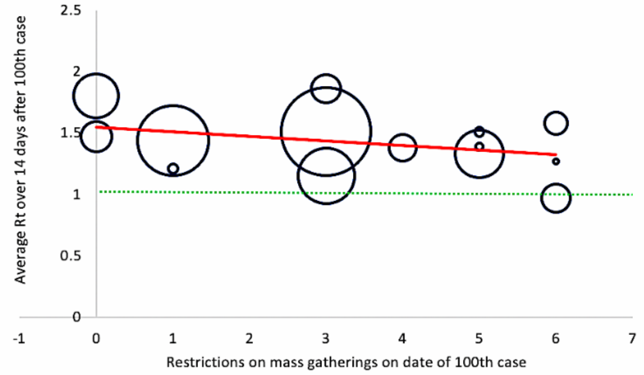

Figure 3

Figure 5 Lockdown-Type Measures on Date of the 100th Case & Average Reproduction Numbers in the Following Two Weeks. *Note.* R*t* = expected number of secondary cases generated by a primary case at time *t*. Please refer to Table 4 for details and specific measures on lockdown-type measures. Each bubble denotes a country, and bubble sizes are proportional to the number of reported cases as of May 28, 2020. The solid red line is the best linear fit of the relationship between lockdown-type measures on the date of the 100th reported case and the average R*t* in the following two weeks. The dashed green line is the R*t* threshold, where a value below one suggests that a sustained outbreak is unlikely if measures remain in place.

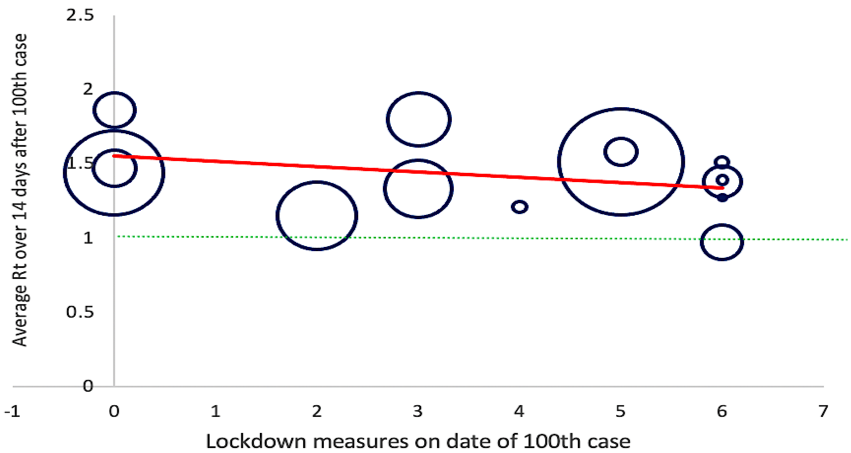

Figure 6

Figure 7 Restrictions on Mass Gatherings on Date of the 100th Case & Average Reproduction Numbers in the Following Two Weeks. *Note.* R*t* =expected number of secondary cases generated by a primary case at time *t*. Please refer to Table 4 for details and specific measures on mass gathering restrictions. Each bubble denotes a country, and bubble sizes are proportional to the number of reported cases as of May 28, 2020.

At first glance, indications for the kind, degree, and temporality of health and containment policy measures in managing COVID-19 transmission seems to differ among Arab MENA states. However, the importance of early stringent policies or the espousal of reasonable physical contact spacing initiatives at a highly early phase of the outbreak is sensible as a control mechanism, maybe even averting the requirement for large-scale shutdowns down the road.

As depicted in Figure 5, both Iraq and Palestine fall to the right of the red dashed line due to their early stringent intervention measures, and therefore they have recorded much lower numbers of COVID-19 cases as of May 28, 2020. Conversely, countries to the left are generally those with less stringent measures early on (one week after the first confirmed case) that might have induced more rapid viral transmission rates, despite high stringency measures shortly after that following the 100th case. In fact, some of these countries (e.g., Morocco and Jordan) were eventually forced into more drastic physical distancing measures to make numbers of COVID-19 cases more manageable, including lockdowns of entire communities.

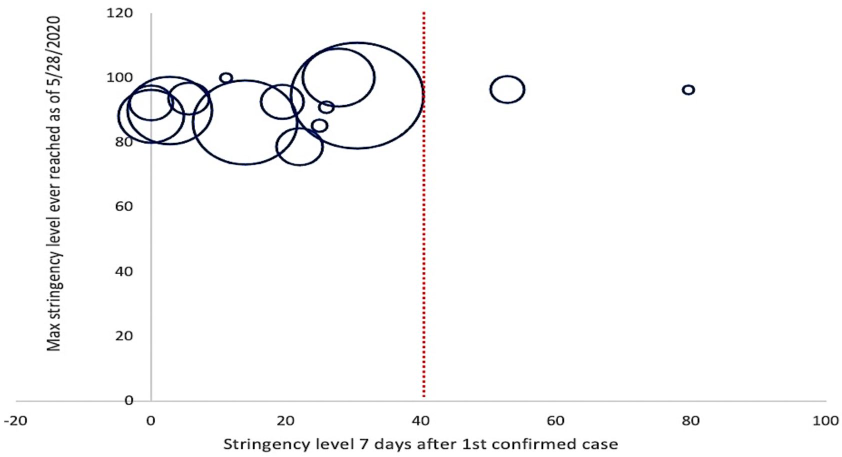

Figure 5

Figure 8 Total COVID-19 Cases and Early Response Measures. Note. The horizontal axis shows a country's stringency level seven days after recording its first COVID-19 case. The vertical axis is the maximum stringency level ever reached as of May 28, 2020. The size of a bubble is proportional to a country's total number of cases.

Observations about the intensive mass testing policies and contact tracing efforts that were implemented in GCC countries are noteworthy; which may have helped achieve more manageable outcomes in GCC member states despite the late implementation of response measures, higher R*t* values (except for Oman), and unknown compliance with government containment policies. Of course, this may not be viable in other neighboring countries in the region that lack the capacity for state-wide contact tracing, especially at the beginning of the pandemic, thus, stressing the essentiality of supplementary policies. Indeed, it is worth noting that numerous countries at first implemented testing protocols centered on the manifestation of symptoms. Consequently, when community transmission is first recognized, it is likely that it is already extensively disseminated, resulting in several covert transmission networks solidly in place (Li and Pei, 2020). According to the findings of Keeling and Hollingsworth (2020), it is clear that in order to effectively curb the initial transmission of the virus, a substantial 70% of close contacts must be successfully traced. However, this task proved to be challenging due to the implementation of limited case detection strategies at the time. It is important to bear in mind that these conclusions are derived from model-based projections, with a basic reproduction number (R_0) of 2.5.

In light of the aforementioned circumstances, it is apparent that even with the successful implementation of optimal COVID-19 testing mechanisms, case identification efforts, and quarantine attempts, the possibility of broad community transmission remains evident. Once established, containment requires implementing intensely disruptive spacing initiatives and massive quarantine policies to control the outbreak (Imperial College COVID-19 Response Team, 2020). However, even if the early implementation of lockdown-type measures could have shifted the dynamics of COVID-19 in countries like Egypt and Algeria, for example, they were unacceptable to many at the time since it is likely to be costly. The feasibility of instituting a clampdown on movement or access is expected to vary with respect to the dominant financial operations of different countries. Wealthier nations or those with a significant technological sector are likely to be more capable of swiftly transitioning to internet-based learning or remote employment arrangements. Conversely, lower-income countries or those with a national economy heavily reliant on revenue from trade and tourism markets may face a significantly different set of challenges in adopting such measures. Ultimately, as the ongoing COVID-19 pandemic persists, it becomes inescapable that the immediate expenses associated with implementing strict measures at an early stage will be significantly less than the enduring costs incurred by reactive interventions in the long haul.

Effect of physical contact and spacing restrictions

We proceeded to examine the influence of the Stringency Index (SI) on the estimated value of R*t* (averaged over 14 days after the 100th case). According to the results of our regression analysis in Table 7, the statistically significant negative coefficient of the SI shows that a 10-point increase in the index score reduces the value of R*t* by 0.062 [95% CI: -0.08, -0.04]. Among other covariates in our regression analysis, the statistically significant negative coefficient for temperature indicates that warmer weather is associated with a lower R*t* value. An increase of 10 degrees Celsius reduces R*t* by 0.15 [95% CI: -0.24, -0.09].

Table 7 . Forecasted Influence of the Stringency Index on COVID-19 Spread

Dependent variable			
R*t* g R*t*			
Stringency Index (SI)	-0.0062** (0.0017)	-0.1733** (0.0365)	
Google mobility			0.0146** (0.0218)
ln GDP per capita	-0.0020 (0.0809)	-0.3031 (1.0257)	0.0288 (0.2526)
ln population density	-0.0602 (0.0304)	0.1455** (0.8158)	-0.0482 (0.1300)
% Age 65+ in population	-0.0217 (0.0242)	0.3981 (0.3735)	-0.0136 (0.0813)
Temperature	-0.0150** (0.0197)	-0.4205** (0.1349)	-0.0373** (0.0475)
_Constant	3.1363*** (0.6761)	11.5786*** (9.7286)	2.4766*** (0.4323)
Number of obs. 14 14 10			
R-squared (R^2) 0.7530 0.6254 0.4194			
Adj R-squared 0.5986 0.3913 0.3691			

Note. The dependent variable R*t* = average R*t* over the 14 days following the date of the 100th case; the dependent variable g = growth rate of total COVID-19 cases between the date of the 100th case and the date 14 days later; mobility data (from Google Community Mobility

Reports) = average percent change in visits to retail and recreation, grocery and pharmacy, parks, transit, and workplaces on the date of the 100th case compared to the median baseline value of the corresponding day of the week during January 3, 2020, to February 6, 2020. Average percent change in mobility was only available for 10 Arab MENA countries and included in the regression model as a proxy measurement of real-life physical distancing practices (a positive coefficient indicates that a reduction in mobility reduces R*t*). Standard errors are in parenthesis. Statistical significance at the 1% level (<0.01) = *** and statistical significance at the 5% level (<0.05) = **.

Regression analyses on the influence of three classifications of physical spacing policies were conducted separately and then together in Table 8. Columns (i) through (iii) in Table 8 seem to support the notion that premature and higher severity initiatives correlate to lower values of R*t* when controlling for country-specific socioeconomic and environmental factors. However, a few statistically significant results were later lost once all the variables were added at the same time and run simultaneously in the regression model.

Table 8. Forecasted Influence of the Kind of Spacing Policies on COVID-19 Propagation

R*t*				
	(i)	(ii)	(iii)	(iv)
Restrictions on international travel				
1	0.1810 (0.1799)			-0.3789 (0.1703)
2	N/A			N/A
3	N/A			N/A
4	N/A			N/A
5	-0.1449 (0.1448)			-0.0641 (0.1413)
6	-0.1544 (0.1312)			-0.0874 (0.1325)
7	-0.4299** (0.1290)			-0.2492 (0.1367)
8	-0.5244*** (0.1353)			-0.3343* (0.1399)

Restrictions on mass gatherings				
1		-0.3472 (0.1546)		-0.2731 (0.1593)
2		N/A		N/A
3		-0.1596 (0.1161)		-0.0419 (0.1424)
4		-0.5253** (0.1273)		-0.3175 (0.1489)
5		-0.2857** (0.1477)		-0.1195 (0.1696)
6		-0.5892** (0.1184)		-0.3235 (0.1582)
Lockdown-type measures				
1			N/A	N/A
2			-0.4429* (0.2858)	-0.5435** (0.2989)
3			-0.2218 (0.2398)	-0.2958 (0.2492)
4			-0.6236*** (0.2685)	-0.4672** (0.2825)
5			-0.2697 (0.0965)	-0.2194 (0.2323)
6			-0.5379*** (0.0833)	-0.4082** (0.2265)
ln GDP per capita	-0.0318 (0.0392)	-0.0491 (0.0395)	-0.0616* (0.0391)	-0.0753** (0.0418)

ln population density	-0.0202 (0.0342)	-0.0249 (0.0332)	-0.0060 (0.0224)	-0.0074 (0.0337)
% Age 65+ in population	0.0037 (0.0088)	0.0026 (0.0084)	0.0058 (0.0083)	0.0037 (0.0084)
Temperature	-0.0292** (0.0055)	-0.0282** (0.0040)	-0.0268** (0.0049)	-0.0263** (0.0052)
_Constant	3.4404** (0.3877)	3.5965** (0.3920)	3.5437** (0.3798)	3.8998** (0.4228)
Number of obs.	14	14	14	14
R-squared (R^2)	0.483	0.513	0.546	0.623
Adj R-squared	0.424	0.472	0.493	0.528

Note. The dependent variable is the average R*t* over the 14 days since the date of the 100th case. The physical distancing measures are those that are in place on the date of the 100th case. Standard errors are in parenthesis. Statistical significance at the 1% level (<0.01) = ***; statistical significance at the 5% level (<0.05) = **; statistical significance at the 10% level (<0.1) = *; N/A = not available.

Based on the far-right column (iv) in Table 8, it appears that – if implemented early – travel restraints on the entirety of overseas countries/regions and confinement-type preventive directives significantly lower R*t* values. As compared to no public safety population health response effort being taken, a total closure of external territorial boundaries and all border crossings reduces R*t* by 0.33 [95% CI: -0.48, 0.03]. While guidelines urging employees to work domestically (ensuing workplace closures) or stay-at-home mandates reduce the value of R*t* by 0.54 [95% CI: -0.80, -0.05]. Likewise, even fragmented and incomplete preemptive or emergency lockdown action plan calling for the closure of some work sectors, or asking the public to stay at home as a means of voluntary mass safety, are found to reduce R*t* by 0.47 [95% CI: -0.70, -0.02]. Conclusively, absolute and all-encompassing obligatory lockdown policies compelling thorough closures of total (other than essential) workplaces – with forceful prohibition of leaving the home next to minimal exceptions given – appear to reduce R*t* by 0.41 [95% CI: -0.53, -0.07].

Robustness checks

Lastly, a routine and essential activity in empirical-based studies are checks of robustness which were later conducted, whereby we examined how specific 'fundamental' coefficients of regression behaved once the model specifications were altered by adding/removing variables. Instead of R*t*, the growth (g) of total cases was used as the dependent variable. Google mobility data was also used in the regression model as a real indicator of physical contact and social spacing policies in practice (instead of legal government reported standards) to assess the ‘on-the-ground’ behavior changes on R*t*. Overall, as evident in Table 7, the regression output and coefficient estimates were largely unaffected.

5. Conclusion

Physical contact and social spacing initiatives have been implemented in almost every country since the early phases of the COVID-19 pandemic. Although previous Western empirical modeling studies have reported the criticality of distancing in curtailing disease propagation, no other empirical-based research have varified these findings exclusively using data from Arab countries/territories. This investigation offers preliminary evidence and quantifies the effects of physical barriers to contact on reducing the reproduction number (R*t*), with a specific focus on public health safety initiatives consisting of freedom of movement constraints, closures of national border crossings, and international travel bans. Moreover, findings suggest that less severe lockdown-type initiatives, such as recommendations to work from home and stay-in-place orders wherever possible, were as promising as total shutdowns in reducing spread; however, the sum of these policies must be in effect early in order to be successful. In essence, when it comes to COVID-19 social spacing strategies and other NPIs – at least for MENA region empirical studies modeled after the Arab world, as this analysis suggests – the 'when' is just as important as the 'what' and the 'how.'

References

[1] Abbott, S., Hellewell, J., Thompson, R. N., Sherratt, K., Gibbs, H. P., and Bosse, N. I., 2020, Estimating the time-varying reproduction number of SARS-CoV-2 using national and subnational case counts. *Wellcome Open Research,* 5, 112.

[2] Castex, G., Dechter, E., and Lorca, M., 2020, COVID-19: cross-country heterogeneity in effectiveness of non-pharmaceutical interventions. *Center for Economic Policy Research Covid Economics,* 14, 175-199.

[3] Chu, D. K., Akl, E. A., Duda, S., Solo, K., Yaacoub, S., and Schünemann, H. J., 2020, Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. *The Lancet,* 395(10242), 1973-1987.

[4] Cori, A., Ferguson, N. M., Fraser, C., and Cauchemez, S., 2013, A new framework and software to estimate time-varying reproduction numbers during epidemics. *American Journal of Epidemiology,* 178(9), 1505-1512.

[5] COVID-19 Response Team, 2020, Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. Imperial College London.

[6] Deb, P., Furceri, D., Ostry, J. D., and Tawk, N., 2020, The effect of containment measures on the COVID-19 pandemic. *Center for Economic Policy Research Covid Economics,* 19, 53-86.

[7] Duc Huynh, T. L., 2020, The COVID-19 containment in Vietnam: what are we doing? *Journal of Global Health,* 10(1), 010338.

[8] Fang, H., Wang, L., and Yang, Y., 2020, Human mobility restrictions and the spread of the novel coronavirus (2019-nCoV) in China. Working paper, National Bureau of Economic Research.

[9] Ferguson, N., Laydon, D., Nedjati-Gilani, G., Imai, N., Ainslie, K., and Baguelin, M., 2020, Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. Imperial College London Report 9.

[10] Friedson, I. F., McNichols, D., Sabia, J. J., and Dave, D., 2020, Did California's Shelter-in-place order work? Early coronavirus-related public health effects. Working paper, National Bureau of Economic Research.

[11] Hale, T., Angrist, N., Kira, B., Petherick, A., Phillips, T., and Webster, S., 2020, Variation in government responses to COVID-19. Working paper, University of Oxford Blavatnik School of Government.

[12] Hartfield, M., and Alizon, S., 2013, Introducing the outbreak threshold in epidemiology. *PLoS Pathogens,* 13(5), e1006415.

[13] Keeling, M. J., and Hollingsworth, T. D., 2020, The efficacy of contact tracing for the containment of the 2019 novel coronavirus (COVID-19). *MedRxiv*, 22, 32-36.

[14] Keita, S., 2020, Air passenger mobility, travel restrictions, and the transmission of the covid-19 pandemic between countries. *Center for Economic Policy Research Covid Economics,* 9, 77–96.

[15] Kissler, S. M., Tedijanto, C., Goldstein, E., Grad, Y. H., and Lipsitch, M., 2020, Projecting the transmission dynamics of SARS-CoV-2 through the post pandemic period. *Science,* 368(6493), 860-868.

[16] Kucharski, A. J., Russell, T. W., Diamond, C., Liu, Y., Edmunds, J., Funk, S., and Eggo, R. M., 2020, Early dynamics of transmission and control of COVID-19: a mathematical modelling study. *The Lancet Infectious Diseases,* 20(5), P553–P558.

[17] Liu, J., Zhou, J., Yao, J., Zhang, X., Li, L., and Xu, X., 2020, Impact of meteorological factors on the COVID-19 transmission: a multi-city study in China. *Science of The Total Environment*, 726.

[18] Li, R., and Pei, S., 2020, Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV2). *Science*, 21, 22-28.

[19] Maloney, W., and Taskin, T., 2020, Determinants of social distancing and economic activity during COVID-19: a global view. *Center for Economic Policy Research Covid Economics,* 13, 157–177.

[20] Prem, K., Liu, Y., Russell, T. W., Kucharski, A. J., Eggo, R. M., and Davies, N., 2020, The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. *The Lancet Public Health,* 5(5), E261–E270.

[21] Qiu, Y., Chen, X., and Shi, W., 2020, Impacts of social and economic factors on the transmission of coronavirus disease 2019 (COVID-19) in China. *Journal of Population Economics,* 33(4), 1127-1172.

[22] Sidik, K., and Jonkman, J. N., 2005, A note on variance estimation in random effects meta-regression. *Journal of Biopharmaceutical Statistics*, 15(5), 823–838.

[23] Sposato, W., 2020, Japan's halfhearted coronavirus measures are working anyway. Foreign Policy, 14 May.

[24] Thompson, R. N., Stockwin, J. E., van Gaalen, R. D., Polonsky, J. A., Kamvar, Z. N., and Demarsh, P. A., 2019, Improved inference of time-varying reproduction numbers during infectious disease outbreaks. *Epidemics*, 29(1), 26.

[25] Tobias, A., 2020, Evaluation of the lockdowns for the SARS-CoV-2 epidemic in Italy and Spain after one month follow up. *Science of The Total Environment,* 725, 138539.

[26] Wang, C. J., Ng, C. Y., and Brook, R. H., 2020, Response to COVID-19 in Taiwan: big data analytics, new technology, and proactive testing. *JAMA*, 323(14), 1341-1342.

[27] WHO, The World Health Organization (Coronavirus disease COVID-19 Situation Report 132), Date of access: 15/06/2021. https://www.who.int/publications/m/item/situation-report---132

[28] Wong, J., Koh, W. C., Alikhan, M. F., Abdul Aziz, A. B. Z., and Naing, L., 2020, Responding to COVID-19 in Brunei Darussalam: lessons for small countries. *Journal of Global Health*, 19(7), 73-80.

[29] Wong, S. Y. S., Kwok, K. O., and Chan, F. K. L., 2020, What can countries learn from Hong Kong's response to the COVID-19 pandemic? *Canadian Medical Association Journal*, 192(19), E511-E515.

[30] World Bank, The World Bank Group (Global Economic Prospects), Date of access: 17/06/2021. https://openknowledge.worldbank.org/entities/publication/d29e6c95-4753-58e8-b368-d03c78cacab5.