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Abstract (Word count: 150)

While the effectiveness of lockdowns to reduce Coronavirus Disease-2019 (COVID-19) transmission is well established, uncertainties remain on the lifting principles of these restrictive interventions. World Health Organization recommends case positive rate of 5% or lower as a threshold for safe reopening. However, inadequate testing capacity limits the applicability of this recommendation, especially in the low-income and middle-income countries (LMICs). To develop a practical reopening strategy for LMICs, in this study, we first identify the optimal timing of safe reopening by exploring accessible epidemiological data of 24 countries during the initial COVID-19 surge. We find that safely reopening requires a two-week waiting period, after the crossover of daily infection and recovery rates – coupled with post-crossover continuous negative trend in daily new cases. Epidemiologic SIRM model-based simulation analysis validates our findings. Finally, we develop an easily interpretable large-scale reopening (LSR) index, which is an evidence-based toolkit – to guide/inform reopening decision for LMICs.

Word count: 3,666 (without Abstract).

Figures and Tables: 4 main figures, 3 main tables, 4 supplementary tables and figure.

Introduction

The Coronavirus Disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), continues to spread worldwide.[1,2] This global health crisis killed millions and infected many folds. It also has a significant economic cost, with output contractions predicted across the vast majority of low-income and middle-income countries (LMIC), and lasting detrimental impacts on fundamental determinants of long-term economic growth prospects in these resource-constrained settings.[3,4] In line with this, it now appears that countries which have the highest COVID-19 death rates, are also among those which suffered the most severe economic downturns.[5] Eventually, given a lower economic resilience and an ever-growing socio-political pressure on the national governments, strict nationwide social distancing interventions (i.e., general lockdown), therefore, had to be lifted either entirely, or in part, by gradually opening selected sectors like hospitality and education.

In many LMICs, large-scale reopening was, however, done abruptly, and in some instances, amidst a continually rising disease count. This premature easing of the community lockdown was followed by adopting various individual (e.g., hygiene practices, facial mask provisions, and physical distancing) and health system measures (e.g., test-trace-isolation of symptomatic cases and their contacts).[6] However, further inefficiencies (e.g., poor adherence to individual measures, insufficient testing and contact-tracing, low rate of self-isolation among those who were "traced") increased the likelihood of new generalized outbreaks in these resource-poor countries. In this regard, subsequent waves have since emerged in Europe[7] and elsewhere, where the resurgence was dealt with new lockdowns.[8,9]

In a national or global epidemic scenario, lockdowns have conventionally shown to be an effective measure in reducing the contact rates within the population; and thereby, in lowering onward transmission.[10] However, important strategic uncertainty remains on the lifting principle of these restrictive measures. For example, although most countries worldwide imposed the strict lockdowns to tackle the initial waves of COVID-19, they differed significantly on the timing of lifting these interventions and reopened while on varying stages of the epidemic trajectory.[11] Hence, it remains unclear what are the principal drivers of successful reopening in various contexts. While World Health Organization (WHO) recommends case positive rate of 5% or lower continuing for two weeks as a threshold for safe reopening,[12] inadequate testing capacity limits the applicability of such a recommendation, especially in the LMIC. Against this backdrop, there remains an urgent need for a standardized evidence-driven approach, which could be utilized as a guiding tool for prompt economic reopening (while reducing the likelihood of a rapid resurgence), in the current and future pandemics.

To address this uncertainty, we have conducted a comprehensive study that aims to: 1) characterize the timing pattern of successful reopening by analyzing global epidemiological data from 24 countries during the initial wave of COVID-19; 2) assess the socio-economic and structural determinants of successful reopening; and 3) develop and validate a simple, evidence-based toolkit to support the reopening decision following a general or localized lockdown in diverse global settings.

Methods

Identification and evaluation of countries with successful reopening

First, we systematically searched the *Worldometer* electronic database[1] for all countries that had reported a nationwide lockdown between March 1 to April 15, 2020 (i.e., the "first wave" of COVID-19 outbreak in most countries). We selected countries which: 1) had reported at least 500 cases, 2) were within 95.5 percentile of the overall mortality and incidence per million population estimates, and 3) had necessary COVID-19 epidemiologic data available from February 1 to June 3, 2020.

Second, we employed longitudinal time-series analyses by plotting daily infection and recovery estimates from each country. We defined a country as "successful" if following the lifting of the lockdown, the observed daily recovery estimates remained higher than the daily new cases for a continuous period of 30 days. Using these pre-specified criteria, we selected 24 countries, of which 16 were found to be "successful". These countries represented all continents and all income categories (9 belonging to the high-income countries, HICs; and 7 were LMICs).[13] Further details on the data collection approach are available as **Appendix** in the Supplementary Material.

Determination of the key dimensions of successful reopening

We conducted Pearson correlation analysis and multivariate-adjusted factor analyses (FA) with *varimax* orthogonal rotation in order to characterize the determinants of reopening decision in the included countries. FA is a statistical method that utilizes the linear relationships among continuous variables under study to reduce them into smaller clusters of summary "factors", retaining as much variance in the original variables as possible. In this analysis, we considered a broad range of potential determinants of successful reopening: gross domestic product (GDP) per capita, "mobility reduction" as a proxy of lockdown execution (calculated as the average percent decline in retail, entertainment, and workplace mobility from the baseline data, obtained from Google Mobility Reports),[14] human development index (HDI, a statistic composite index of life expectancy, education and per capita income indicators, which are used to rank countries into four tiers of human development),[15] social progress index (SPI, measures the extent to which countries provide for the social and environmental needs of their citizens)[16], and worldwide governance indicators (WGI, which includes accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption indicators)[17].

Development of a large-scale reopening index

We employed the following steps to develop a novel large-scale reopening (LSR) toolkit. First, we analyzed 5-day moving average estimates for infected (*I*) and recovered (*R*) cases from all successful countries to construct the country-specific *I-R* trajectories over a 3-month period. Second, from each country, we extracted data on four key daily variables: deaths per million (*D*), positive cases per million tests (*P*), recovered cases per million (*R*), and new confirmed cases per million (*C*). Third, we created sub-indices for *C*, *D*, and *P* variables, where maximum and minimum values are the corresponding estimates for all included countries, by employing the following equation:

$$Sub\text{-}index = 1 - \left(\frac{Actual\ value\ per\ million - Minimum\ value}{Maximum\ value - Minimum\ value}\right)$$

In these included countries, the maximum value for death per million population was 18·81, cases per million population was 189·07, and positive cases per million tests was 53·42.

Fourth, we applied a multiplier (*m*) that denotes the deficit between recovered and infected:

$$Multiplier\ (m) = \frac{Daily\ Recovery\ (R) - Daily\ New\ Cases\ (C)}{Daily\ Recovery\ (R) + Daily\ New\ Cases\ (C)}$$

Fifth, we constructed country-specific LSR index estimates, using the following equation:

$$LSR\ Index = m\left(\frac{D+C+P}{3}\right)$$

Finally, to account for any potential variations by socioeconomic and governance factors, we recalibrated all LSR indices by a multiplication factor (ω) as follows:

$$Recalibrated\ LSR\ Index = \omega \times LSR\ Index$$

where ω is a scaled average of GDP, SPI, HDI, and WGI. To estimate ω, we first normalized (0-1) GDP, SPI, HDI, and WGI to bring all them in a comparable scale as follows:

$$X_{n,i} = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

Here, $X_{n,i}$ is each of the country-specific normalized values of the variables (i.e., GDP, SPI, HDI, and WGI) where *i* refers to country index, X_i is the corresponding value before normalization, X_{min} and X_{max} refer to the minimum and maximum values of the variables. We then estimated ω for each country from the average of the corresponding normalized variables as follows:

$$\omega_i = \frac{X_{n,i}^{GDP} + X_{n,i}^{SPI} + X_{n,i}^{HDI} + X_{n,i}^{WGI}}{4}$$

Based on LSR estimates and I-R dynamics, we define "waiting period" (WP) as the number of continuous days, following the *I-R* crossover, that a country waited to reopen the economy.

Validation of the index and illustration of application

To demonstrate the impacts of actual versus index-driven reopening, we conducted mathematical modelling based on the epidemiologic Susceptible-Infected-Recovered-Mortality (SIRM) compartmental model.[18] Under this framework, we simulated hypothetical scenarios to investigate the impacts of 'premature' versus 'safe' reopening scenarios on the likelihood of triggering a second infection wave and extended lockdown days.

We employed the following four conventional equations of the SIRM model:

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I - \mu I$$

$$\frac{dR}{dt} = \gamma I$$

$$\frac{dM}{dt} = \mu I$$

In these equations, *S, I*, *R and M* denote susceptible, infected, recovered and mortality, respectively; while parameters β, γ, and μ represent transmission, recovery and mortality rates, respectively. For Germany and Iran (selected as example countries to illustrate the successful and unsuccessful scenarios, respectively), various clinical parameters and transmission dynamics used for the SIRM analyses have been summarized in **Supplementary Table 1**. Briefly, we assumed initial susceptible/exposed (S_o) estimates of 24,000 and 12,500, and basic reproduction number (R_o) of 2·8 and 2·6, respectively (which are within the best-estimated R_o range for COVID-19).[19,20] The impacts of reopening in the SIRM model were simulated based on the amplification of the number of exposures at the reopening date, by multiplying the fitted baseline S at the reopening date with the corresponding R_o. For this analysis, we applied the observed COVID-19 data of these countries to fit the observed infection (I) curve. Finally, based on the fitted I-curve, we simulated the model with actual reopening and compared with index-based (desired) reopening.

Results

Key characteristics of the included countries

Various demographic, socioeconomic, structural and lockdown-related characteristics of the 24 included countries have been summarized in **Table 1**. Given large variability in the WP among countries and small sample countries studied, we prefer to use median estimates, which is more stable and do not get influenced by one or two extreme values. Our estimates show that the median WP for HIC is 26 and LMIC is 15 days. The WP in the majority successful HICs and LMICs were longer than 14 days, whereas only two countries (Italy and Malaysia) had a WP of less than 7 days. By contrast, all unsuccessful countries had a WP shorter than 7 days (median duration was 0 days) (**Table 1**). Additionally, compared with the unsuccessful countries, all successful HIC and LMICs had generally higher average HDI, SPI and WGI estimates (**Table 1**). However, the average reductions in the overall mobility estimates during lockdown were broadly similar across all included countries. Saudi Arabia was the only HIC among all unsuccessful countries (**Table 1**).

Social and structural determinants of economic reopening

Results of the multivariate-adjusted factor analysis (FA), to investigate any potential clustering of variables associated with successful reopening, have been summarized in **Table 2**. Briefly, FA indicates that two factors were sufficient to optimally explain the data variance based on the Eigenvalue criterion. Together, they accounted for 57.4% of the variance in the included variables. WGI, GDP, SPI, HDI loaded highly (0.86 to 0.97) on factor 1 where WP loaded moderately (0.47) – indicating that WP (as a proxy indicator of reopening decision) is importantly associated with governance, socio-economic, and human development vectors. In contrast, there was weak loading of WP on factor 2 (0.03), indicating a weak representation of WP in this factor. In both factors, low to moderate loadings of mobility reduction and lockdown duration (-0.26 to -0.01) implied somewhat lesser relevance of these circumstances to WP. The country-specific scores derived from the factor analyses have been given in **Supplementary Table 2**. Additionally, in the subsidiary Pearson's unadjusted correlation analysis, WGI, GDP, SPI, HDI and lockdown duration were each correlated moderately ($r = 0.32$ to 0.45) with WP (**Supplementary Figure 1**).

Features of the proposed large-scale reopening index

Figures 1 and **2** present *I-R* trajectories (top panel; based on time series COVID-19 data of daily new cases and recoveries), and corresponding LSR index (bottom panel; based on relative slope of infection and recovery from the crossover to reopening) in successful HICs and LMICs, respectively. The corresponding trajectories for the unsuccessful countries have been provided in **Supplementary Figure 2**. In all countries, the calculated LSR index, calibrated for country-specific socioeconomic and governance factors (**Table 3**), aligned well with the country-specific observed *I-R* dynamics, with a neutral value representing the time point of *I-R* crossover and a positive slope denoting that the recovery rates have surpassed the new infection rates.

The recalibrated LSR index values differed importantly across successful countries, with the median LSR index value of 35.72 in the HICs and 21.64 in the LMICs (Table 3). We further examined the WP values by two subcategories of recalibrated LSR index: (i) a "high positive" index (defined as

LSR index >20), which denotes a higher (and desirable) deviation between recoveries and infections; and (ii) a "low positive" index (defined as LSR index of ≤20). We found that for both HICs and LMICs that reopened successfully with the "high positive" LSR index (and therefore had a lower likelihood of immediate resurgence) the median of WP was 24 days, which was 15 days for "low positive" LSR index. (Table 3 and Figure 3). These LSR based estimates are robustly consistent with our earlier findings with Income based classification of countries, suggesting an approximately minimum 2 weeks WP is required, after the I-R crossover for safe reopening.

Validation of the LSR index and an illustration of use

Figure 4 illustrates the likely impact of premature and timely reopening in Germany and Iran as examples to illustrate successful and unsuccessful scenarios. The results from the SIRM modelling demonstrate that if Germany had a hypothetical early reopening – e.g., on the day of *I-R* crossover – this would have triggered a significantly higher immediate resurgence. To quantify this difference: there would have been 3,828 additional daily new cases during the simulated "after peak" if reopening happened at the crossover date, compared to the case counts during the peak following the actual reopening date (**Figure 4**, top panel).

In contrast, the actual reopening by Iran (i.e., 3 days following the *I-R* crossover) led to a significant resurgence (shown by the orange bars for "observed events"; **Figure 4**, bottom panel). However, if Iran reopened 20 days after *I-R* crossover (i.e., in accordance to calculated LSR index for Iran), a significantly lower second peak would have resulted. To quantify, the simulated after peak for the actual reopening would have resulted in 3,534 daily cases, whereas following the LSR-based reopening, there would be only 1,401 daily cases during a simulated after peak (**Figure 4**, bottom panel). These results indicate that the LSR-based reopening approach for Iran would have prevented a higher resurgence of the disease (and its detrimental consequences on local health systems and economy).

Discussion

We found that "successful" countries reopened the economy after the daily recovery rate intersects the infection rate from below while observing the continuous negative trend in the daily new cases. While median WP for successful HIC was 26 days, it was 15 days for successful LMIC, which we propose as the minimum WP threshold (after *I-R* crossover) required for safe reopening. This two-week waiting period for LMIC is consistent with the current epidemiological understanding given that the median incubation period of COVID-19 is approximately five days, with 97% will show symptoms in about 11 days, and 99% will do so within 14 days of exposure.[21] When the daily recovery surpasses the daily new infection, it points towards the effectiveness of the measures taken to control the spread of the virus, bringing the reproduction rate (R_0) down from 2·6 to 0·37.[22] Positive LSR index for a minimum consecutive 14 days, as proposed in this study, suggests that it is likely to prevent a quick infection wave – providing a safe reopening passage for the economies. Since the infection and mortality risks of COVID-19 vary considerably by age (older population face higher risk), the WP gap observed between HIC and LMIC is also expected – given the lower fertility and relative higher older population in the HIC compared to LMIC.[23]

Although WHO suggested that case positive rate of 5% or lower lasting for two weeks is an indicator for safe reopening,[24] calculating case positivity rates can be complicated by use of duplicative or irrelevant data; and especially in the LMICs, where a low case positive rate may simply reflect a lack of generalizable testing operation, rather than indicating a well-executed suppression strategy[25, 26]. Moreover, non-random voluntary testing by individuals, who are either symptomatic or exposed, is imprecise, since estimating the true positivity rate requires regular and repeated testing by a representative sample – irrespective of their illness status. On the other hand, the proposed index-based reopening strategy offers a more holistic approach as the index incorporates both infection and recovery dynamics as a function of number of tests performed.

Overall, in this study, we have developed, validated and illustrated the use of an easily interpretable toolkit for economic reopening that complements the current WHO prescribed safe re-opening strategy. In particular, this toolkit could be adapted for the LMIC where complex, resource-intensive approaches to monitor the epidemic growth (e.g., by generating real-time effective reproduction number or *R* estimates)[19] to inform decisions, remain unfeasible. We have developed the LSR index by using empirical data from 24 worldwide countries, and recalibrated the indices by relevant local socioeconomic and governance factors. The recalibration helped to standardize the index by incorporating country-specific social and economic disparities. Our results indicate that the recalibrated index reflect the corresponding dynamics between the infection and recovery counts accurately. Additionally, for the countries included in this study, a highly successful reopening (characterized by LSR index values of >20 and a sustained positive slope) demonstrated median 3-4 weeks of waiting period following the infection-recovery crossover. This reinforces the fact that in order to avoid a rapid resurgence (and the protecting health systems overflow), suppression strategies need to be sufficiently prolonged to lower the community transmission rates adequately, given information uncertainty (and detection lag) associated with epidemiologic data. Finally, we found that longer waiting period (as a proxy of reopening decision) is importantly associated with governance, socio-economic and human development factors especially social welfare safeguarding countries.

The LSR index described here comprises several features that may confer important advantages as a novel toolkit. First, our extensive analyses involve and complimentary epidemiological, demographic, structural and social mobility datasets, collected from countries located in diverse economic and geographical settings. This increases the validity and generalizability of this index-based toolkit and provides a global relevance to this work. Second, our methods framework was shaped by established approaches employed in other benchmark global toolkits, such as Human Development Index, where statistical composite indices are constructed based on combining multiple tiers of subnational indicators[15]. Third, our index offers a simplicity of the approach with respect to local adaptability and easy interpretability in a resource-constrained context. For example, adapting this toolkit involves: (a) only a few relatively simple calculating steps, (b) routinely collected disease and other information, and (c) no requirements for considering complex health system-wide data often unavailable in resource-poor settings. Furthermore, the ability of the toolkit to illustrate disease and recovery dynamics in positive or negative quantifiable values can be readily interpretable by the local healthcare authorities and policymakers in the LMICs.

Fourth, our index development involves application of pragmatic equations that do not assume availability of all sub-indices. For example, because the multiplier employed (which determines the index crossover) is principally a function of daily incidence and recovery rates, absence of any sub-index (owing to unavailability of relevant local data, such as tests per million infections) would not affect the overall interpretation, producing estimates broadly similar in direction and magnitude if these data were available. Fifth, the approach, which we used for construction and recalibration of the reopening index, allows further revision and local contextualization. Therefore, it should enable agile updating of the index as relevant new epidemiological (and other related) data emerge about COVID-19. Finally, a flexible method used to construct the indices also implies that, in addition to national lockdowns, this toolkit could also be: (a) incorporated in localized or regional lockdowns, and (b) usefully adapted for other infectious disease epidemics in these geographical areas beyond COVID-19 pandemic.

Since we derived our indices based on country-specific disease dynamics and other publicly-available sub-index data solely from a selected subset of HICs and LMICs with available information, the findings may have somewhat limited the wider scope of our index contextualization. However, our selected HIC and LMIC subsets represent geographical, economical, and population gradients, and therefore could be considered large scale representative set of countries to infer the results. In countries with available information, the quality of recorded data with respect to completeness and accuracy of data collection, reporting and analysis may differ importantly between high and low-income settings, which could have biased the estimated index.[27] The derived index represents a national-level arithmetic aggregate that could potentially obscure many disparities within the countries (such as by economic, ethnic and gender groupings)[28,29]. Future studies should further uncover any within-country variation, and adjust the indices accordingly. Our SIRM analyses to estimate the impact of index-based reopening on subsequent resurgence may have been limited by several underlying transmission parameter assumptions used to construct these hypothetical models.[18] As more countries experience infection waves in coming months, further comprehensive modelling studies will, therefore, be needed to better investigate these effects. However, data available to us were insufficient to explore this issue in detail for all included countries.

Our findings may have some implications. To the best of our knowledge, this is the first study that systematically assessed all successfully reopened countries during the initial wave of the COVID-19 pandemic, and analyzed relevant national-level data in order to develop a simple, scalable toolkit for informing economic reopening. The study has a global relevance since achieving a vaccine-induced herd immunity globally may still require years,[30,31,32] and the success of mitigation interventions (such as test-trace-isolate) has generally been limited worldwide.[22,23] Therefore, suppression strategies, despite their economic consequences, may remain an unavoidable choice to control significant community resurgences of COVID-19 or other future pandemics.[33] Therefore, our toolkit, based primarily on case and recovery rates, offer a potentially more practicable alternative for the LMICs.

However, further context-specific research is warranted to tailor this index by local health system circumstances and strategic priorities.

In conclusion, our analyses recommend that safe reopening requires minimum two weeks waiting period, after the crossover of daily infection and recovery rates – coupled with post-crossover continuous negative trend in daily new cases. To facilitate this recommendation, we have developed, validated, and illustrated the use of an easily interpretable index as a toolkit for economic reopening. This simple, flexible toolkit could be readily adapted for low and middle-income countries and utilized as a guiding instrument for a prompt reopening of the economy while reducing the likelihood of a rapid resurgence.

Data Availability

Data used in this study are described in main text, figures, tables, and Supplemental notes.

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Author Contributions

All authors contributed to the formation of the concept and analyses plan. KI performed the analyses, guided by AS, NA and RC. ST and AS were responsible for data collection and development of cleaned figures and Tables. AS was responsible for the overall coordination of the project. RC wrote the manuscript with inputs from all co-authors.

Additional Information

The authors have no conflicts of interest to declare that the relevant the content of this article.

Table 1. Lockdown, reopening, demographic, and economic characteristics of the 24 countries included in the study

Country	Lockdown and reopening characteristics				Demographic and economic characteristics				
	Date of lockdown	Date for reopening	Date for *I-R* Crossover	Waiting Period, days	GDP/capita, in '000 USD	Mobility Reduction, %	HDI, 2018	SPI, 2019	WGI, 2018
Successful high income countries									
Australia	4/2/2020	5/14/2020	4/5/2020	39	49.38	-33.31	0.94	88.02	1.58
Germany	3/21/2020	5/6/2020	4/14/2020	22	52.56	-45.13	0.94	88.84	1.50
New Zealand	3/25/2020	5/13/2020	4/10/2020	33	40.75	-63.30	0.92	88.93	1.81
Denmark	3/3/2020	5/10/2020	4/13/2020	27	54.36	-33.45	0.93	90.09	1.68
Austria	3/16/2020	4/30/2020	4/4/2020	26	53.88	-68.04	0.91	86.40	1.46
Spain	3/14/2020	5/26/2020	4/25/2020	31	39.04	-75.82	0.89	87.47	0.81
Italy	3/9/2020	5/4/2020	4/29/2020	5	40.92	-70.21	0.88	85.69	0.49
Japan	4/7/2020	5/24/2020	4/30/2020	24	42.07	-23.06	0.92	88.34	1.34
Singapore	4/8/2020	6/2/2020	5/13/2020	20	94.11	-62.15	0.94	83.23	1.64
Overall, mean (SD)	-	-	-	*25.2 (9.6)*	*51.89 (16.90)*	*-52.72 (19.24)*	*0.92 (0.02)*	*87.45 (2.07)*	*1.37 (0.44)*
Overall, Median				***26***					
Successful middle/low income countries									
Turkey	3/21/2020	5/4/2020	4/25/2020	9	28.00	-47.91	0.81	67.49	-0.48
Croatia	3/23/2020	5/11/2020	4/18/2020	23	14.95	-34.02	0.84	79.21	0.46
Mali	3/25/2020	7/24/2020	7/9/2020	15	0.93	-12.09	0.43	45.98	-0.96
Malaysia	3/18/2020	6/10/2020	6/8/2020	2	11.14	-39.05	0.80	74.17	0.43
Thailand	3/21/2020	6/15/2020	4/10/2020	66	7.79	-30.05	0.77	67.47	-0.20
Vietnam	4/1/2020	4/23/2020	4/5/2020	18	2.74	-32.87	0.69	68.85	-0.33
Hungary	3/27/2020	5/18/2020	5/7/2020	11	28.80	-41.68	0.85	78.77	0.46
Overall, mean (SD)	-	-	-	*20.6 (21.1)*	*13.48 (11.24)*	*-33.95 (11.37)*	*0.74 (0.15)*	*68.85 (11.26)*	*-0.09 (0.56)*
Overall, Median				***15***					
Unsuccessful countries									
Romania	3/25/2020	5/12/2020	5/10/2020	2	26.66	-51.34	0.82	74.81	0.16
Saudi Arabia	3/15/2020	5/31/2020	5/26/2020	5	53.89	-44.95	0.86	63.95	-0.23
Iran	3/13/2020	4/11/2020	4/9/2020	2	20.89	-	0.80	65.15	-1.00

Pakistan	3/23/2020	4/10/2020	NA	0	5.54	-53.60	0.56	48.20	-0.97
Colombia	3/25/2020	4/27/2020	NA	0	14.50	-62.96	0.76	70.31	-0.18
Poland	3/31/2020	4/20/2020	NA	0	29.92	-33.93	0.87	81.25	0.65
Ghana	3/30/2020	4/23/2020	NA	0	4.50	-45.00	0.60	61.75	0.05
Ukraine	3/16/2020	5/11/2020	NA	0	8.70	-43.73	0.75	66.97	-0.68
Overall, mean (SD)	-	-	-	*1.1 (1.8)*	*20.6 (16.6)*	*-47.93 (9.14)*	*0.75 (0.12)*	*66.55 (9.76)*	*-0.28 (0.58)*
Overall, Median				***0***					

I-R, infection-recovery; GDP, gross domestic product; HDI, human development index; SPI, social progress index; WGI, world governance indicator; SD, standard deviation; NA, not applicable.
Mobility reduction during lockdown is calculated from the Google Mobility reports for each country.
I-R crossover denotes time point when the daily recovery rate exceeds the daily new case rate.

Table 2. Major extracted factors and associated loadings of waiting period and the potential drivers

Variables	**Factor 1**	**Factor 2**
WGI	0.95*	0.06
GDP	0.97*	0.24
SPI	0.91*	0.41
HDI	0.86*	0.30
Mobility reduction	-0.01	-0.16
Lockdown duration	-0.01	-0.26
Waiting period	*0.47*	*0.06*

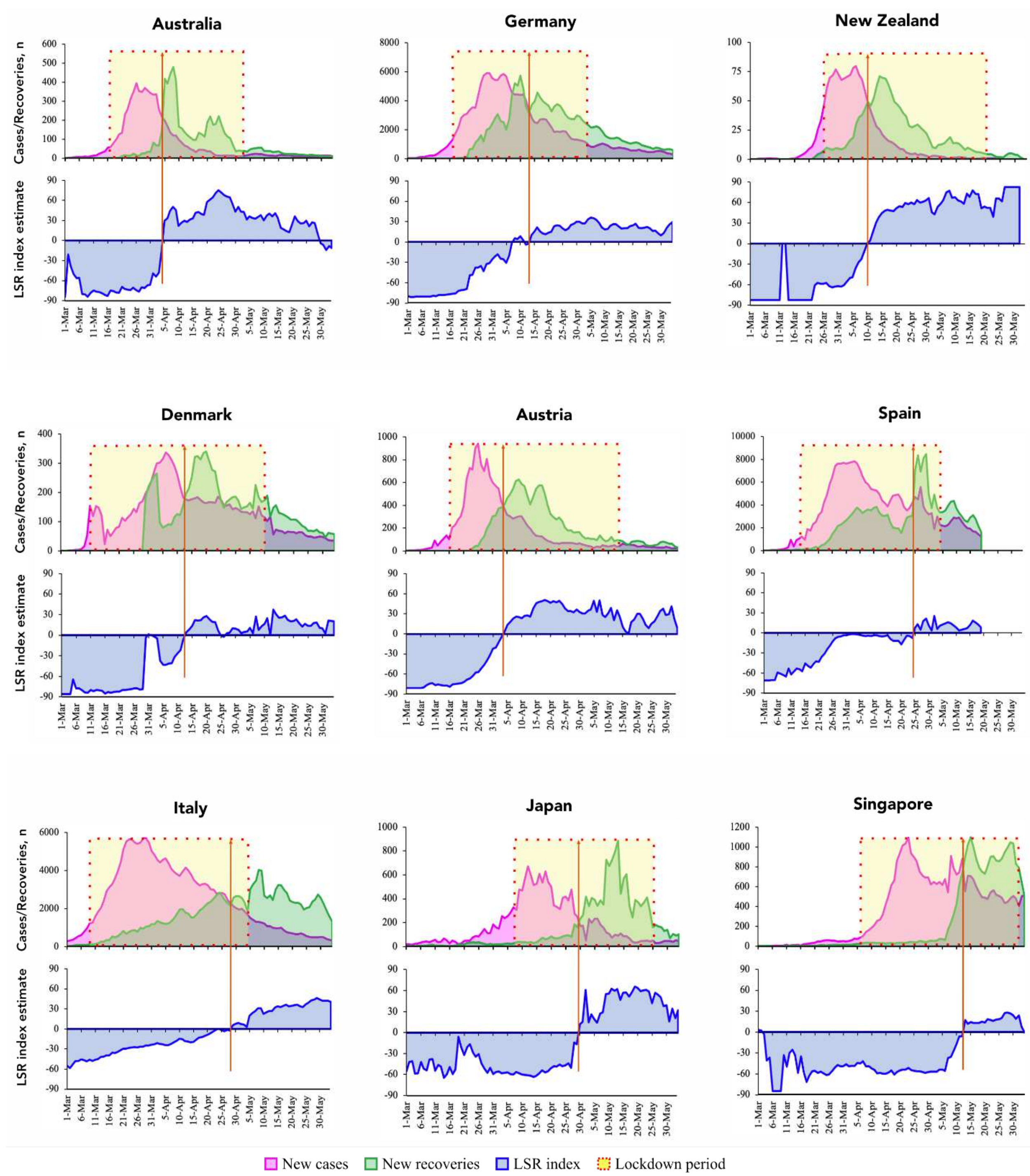
* Denotes dominant loadings for each factor. WGI, world governance indicator; GDP, gross domestic product; SPI, social progress index; HDI, human development index. WP was set to zero for the unsuccessful countries.

Table 3. Recalibration of the LSR index by country-specific socioeconomic and governance indicators

Country	Lockdown duration, days	Crude LSR index at the reopening date	GDP per capita (in '000 USD, scaled)	HDI, 2019 (scaled)	SPI, 2020 (scaled)	WGI, 2018 (scaled)	Average scaling for GDP, HDI, SPI, and WGI	LSR Index at the reopening date (recalibrated)
Successful high-income countries								
Australia	42	48.67	0.84	1.00	0.98	0.92	0.93	45.46
Germany	46	43.58	0.71	1.00	0.96	0.89	0.89	38.76
New Zealand	49	70.18	0.64	0.96	0.99	1.00	0.90	63.06
Denmark	68	19.30	0.92	0.98	1.00	0.95	0.96	18.59
Austria	45	40.42	0.77	0.95	0.94	0.88	0.88	35.72
Spain	73	16.00	0.45	0.91	0.92	0.64	0.73	11.69
Italy	56	4.53	0.50	0.89	0.89	0.53	0.70	3.19
Japan	47	74.61	0.61	0.95	0.96	0.83	0.84	62.54
Singapore	55	9.30	1.00	0.99	0.85	0.94	0.94	8.78
Overall, mean (SD)	*53.44 (10.74)*	*36.29 (25.69)*	*0.71 (0.18)*	*0.96 (0.04)*	*0.94 (0.05)*	*0.84 (0.16)*	*0.87 (0.09)*	*31.98 (22.64)*
Successful middle/low income countries								
Turkey	44	41.19	0.13	0.74	0.46	0.19	0.38	15.57
Croatia	49	37.53	0.22	0.80	0.77	0.52	0.58	21.64
Mali	121	34.81	0.00	0.00	0.00	0.02	0.00	0.15
Malaysia	84	50.93	0.16	0.74	0.65	0.51	0.52	26.27
Thailand	86	85.86	0.11	0.66	0.51	0.29	0.39	33.59
Vietnam	22	69.23	0.03	0.52	0.47	0.24	0.31	21.71
Hungary	52	11.00	0.24	0.82	0.75	0.52	0.58	6.40
Overall, mean (SD)	*65.43 (33.30)*	*47.22 (24.45)*	*0.13 (0.09)*	*0.61 (0.29)*	*0.52 (0.26)*	*0.33 (0.20)*	*0.39 (0.20)*	*17.90 (11.53)*
Median waiting period for High LSR (LSR>20) = 24								
Median waiting period for Low LSR (LSR≤20) =15								
Unsuccessful countries								
Romania	48	13.40	0.19	0.76	0.69	0.41	0.51	6.85
Saudi Arabia	77	21.07	0.35	0.84	0.38	0.27	0.46	9.70
Iran	29	25.08	0.07	0.72	0.44	0.00	0.31	7.73
Pakistan	18	-46.09	0.01	0.26	0.02	0.01	0.08	-3.46
Colombia	33	-52.40	0.09	0.65	0.59	0.29	0.40	-21.18
Poland	20	-48.14	0.23	0.87	0.82	0.59	0.63	-30.16
Ghana	24	-73.90	0.02	0.33	0.38	0.37	0.28	-20.35
Ukraine	56	-26.44	0.04	0.63	0.57	0.11	0.34	-9.00
Overall, mean (SD)	*38.13 (20.60)*	*-23.43 (38.19)*	*0.12 (0.12)*	*0.63 (0.22)*	*0.49 (0.24)*	*0.26 (0.20)*	*0.38 (0.17)*	*-7.48 (15.20)*

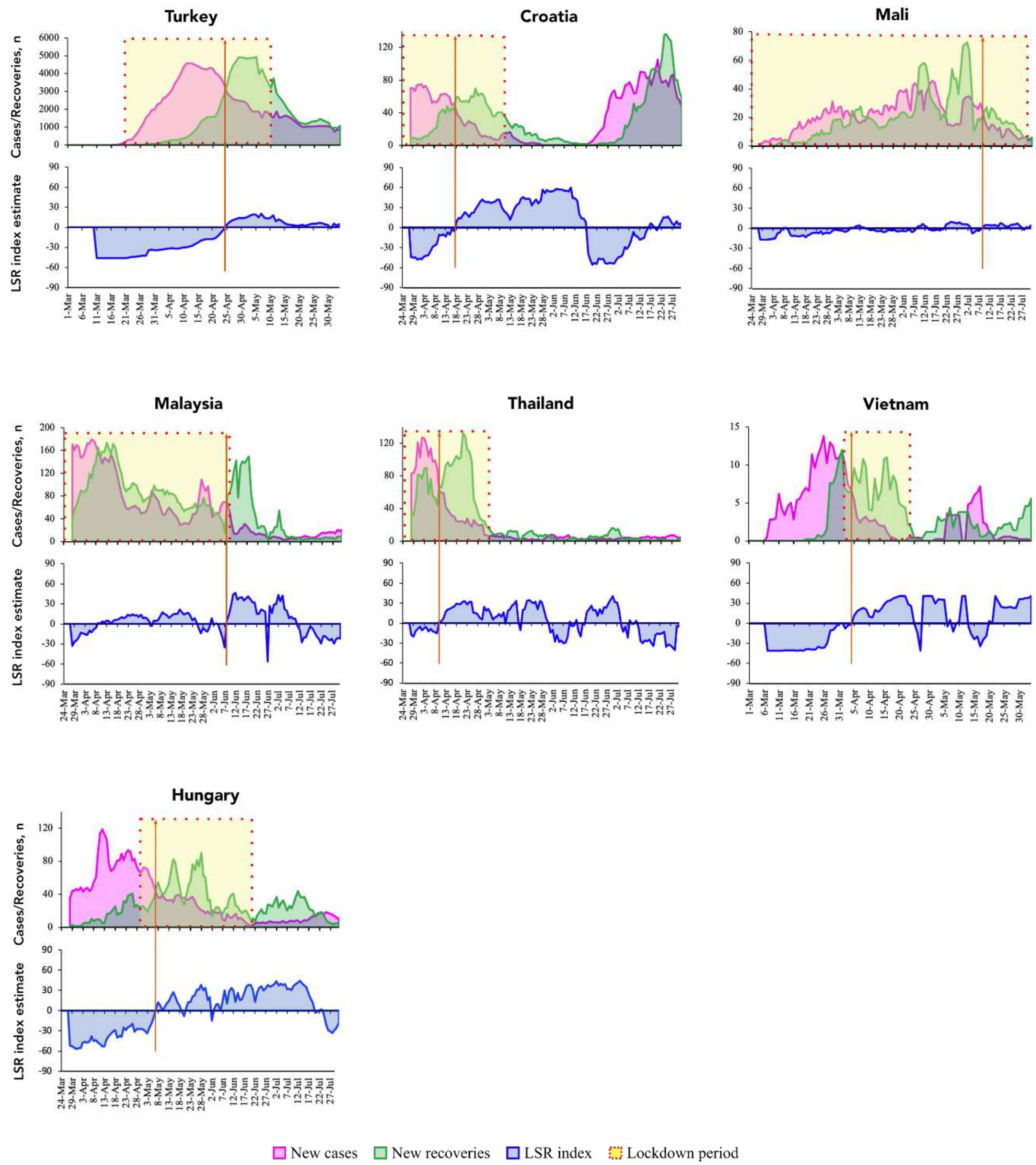
LSR, Large-scale reopening; HDI, Human Development Index; SPI, Social Progress Index; WGI, World Governance Indicator; SD, standard deviation.

Figure 1. Infection-recovery (top panel) and the corresponding LSR index (bottom panel) trajectories in the successful high-income countries



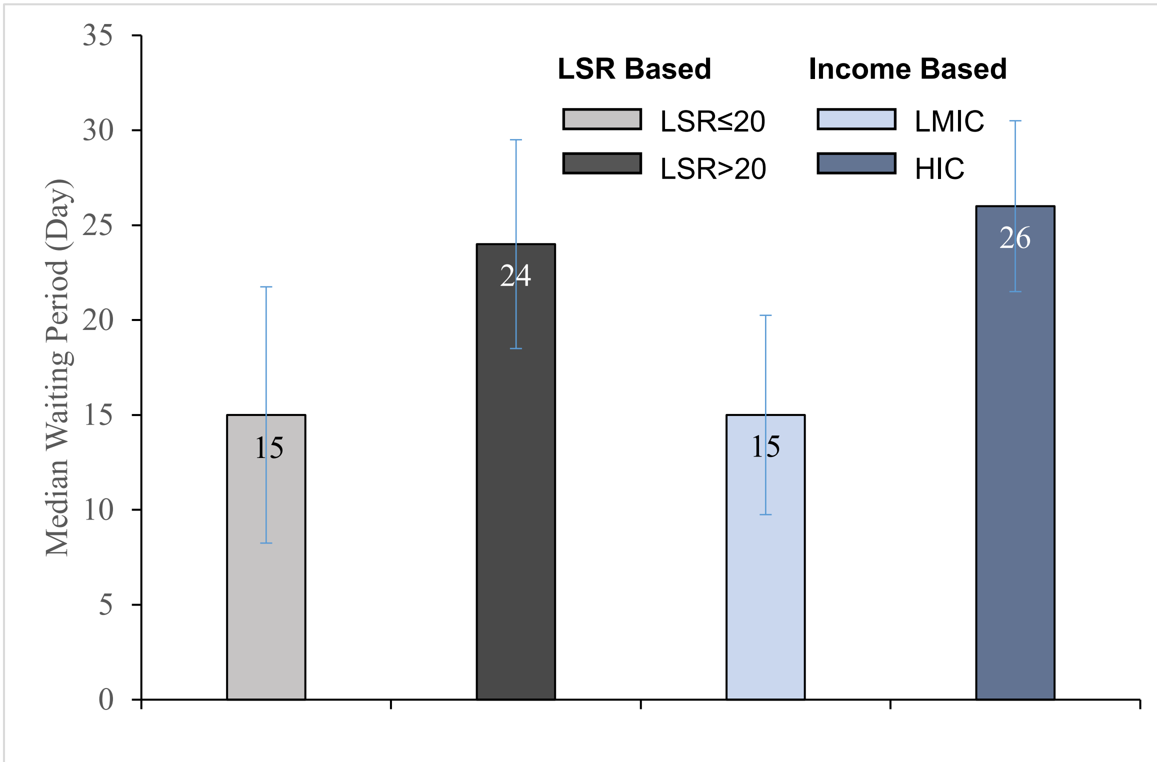
The orange vertical lines in the plots indicate the I-R crossover time point.

Figure 2. Infection-recovery (top panel) and the corresponding LSR index (bottom panel) trajectories in the successful low/middle-income countries



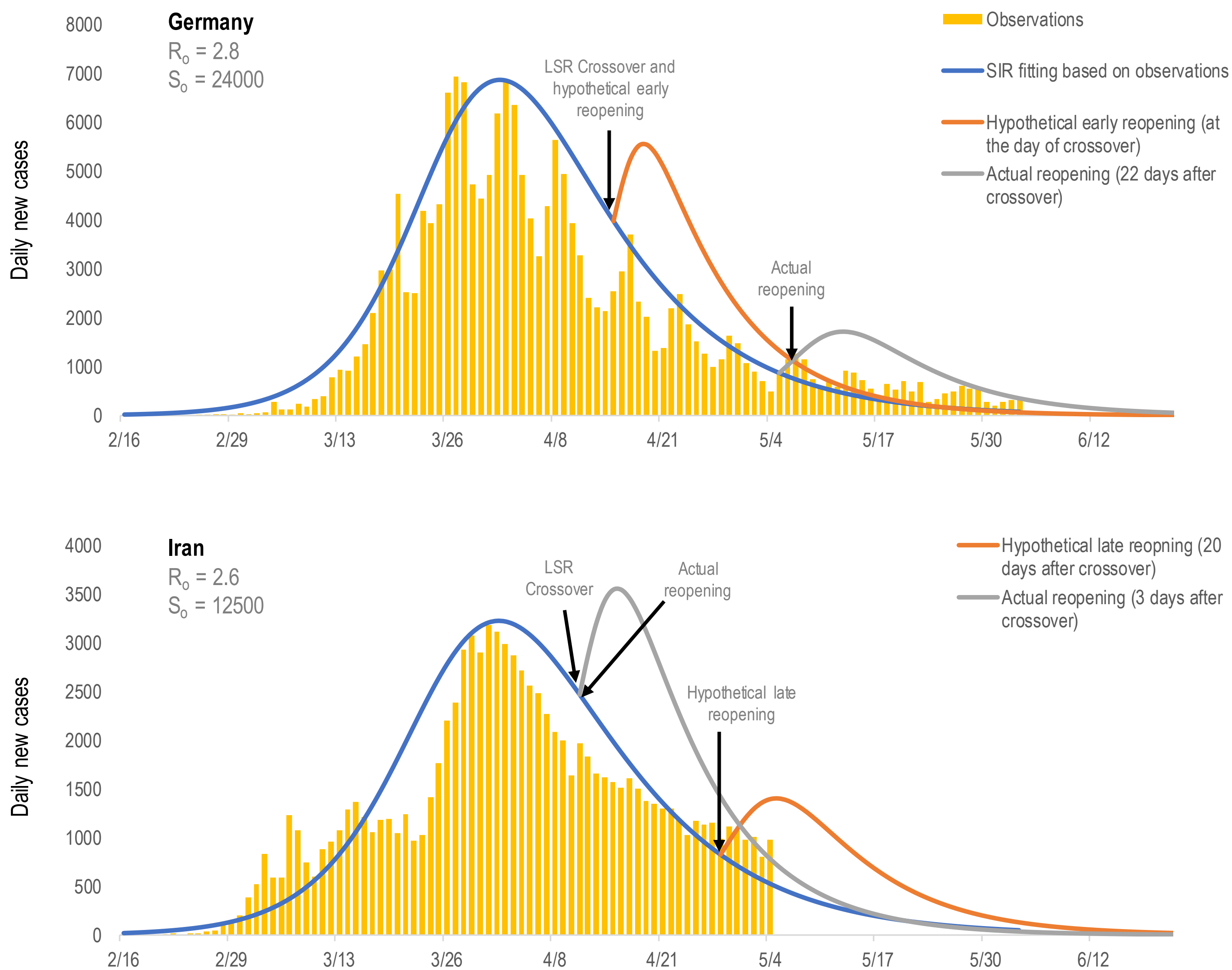
The orange vertical lines in the plots indicate the I-R crossover time point.

Figure 3. Median of waiting periods by two successful country groups (HIC and LMIC) and LSR index classes (LSR>20 and LSR≤20). The vertical error bars represent inter-quartile range.



LSR, Large-scale reopening; LMIC, Low-income and middle-income countries; HIC, high Income countries.

Figure 4. Impact of actual versus hypothetical index-based reopening on new daily cases



Figures

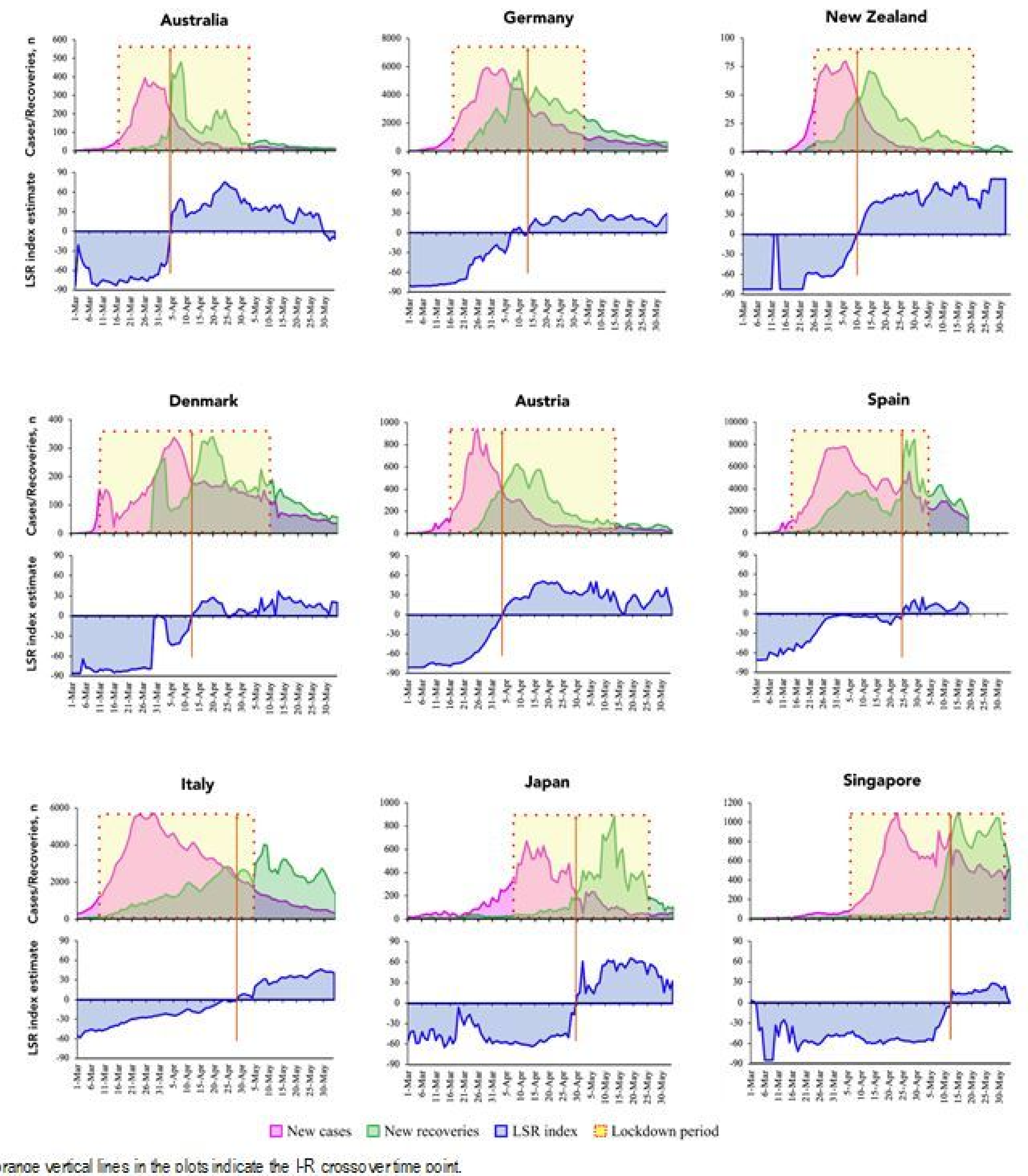


Figure 1

Infection-recovery (top panel) and the corresponding LSR index (bottom panel) trajectories in the successful high-income countries

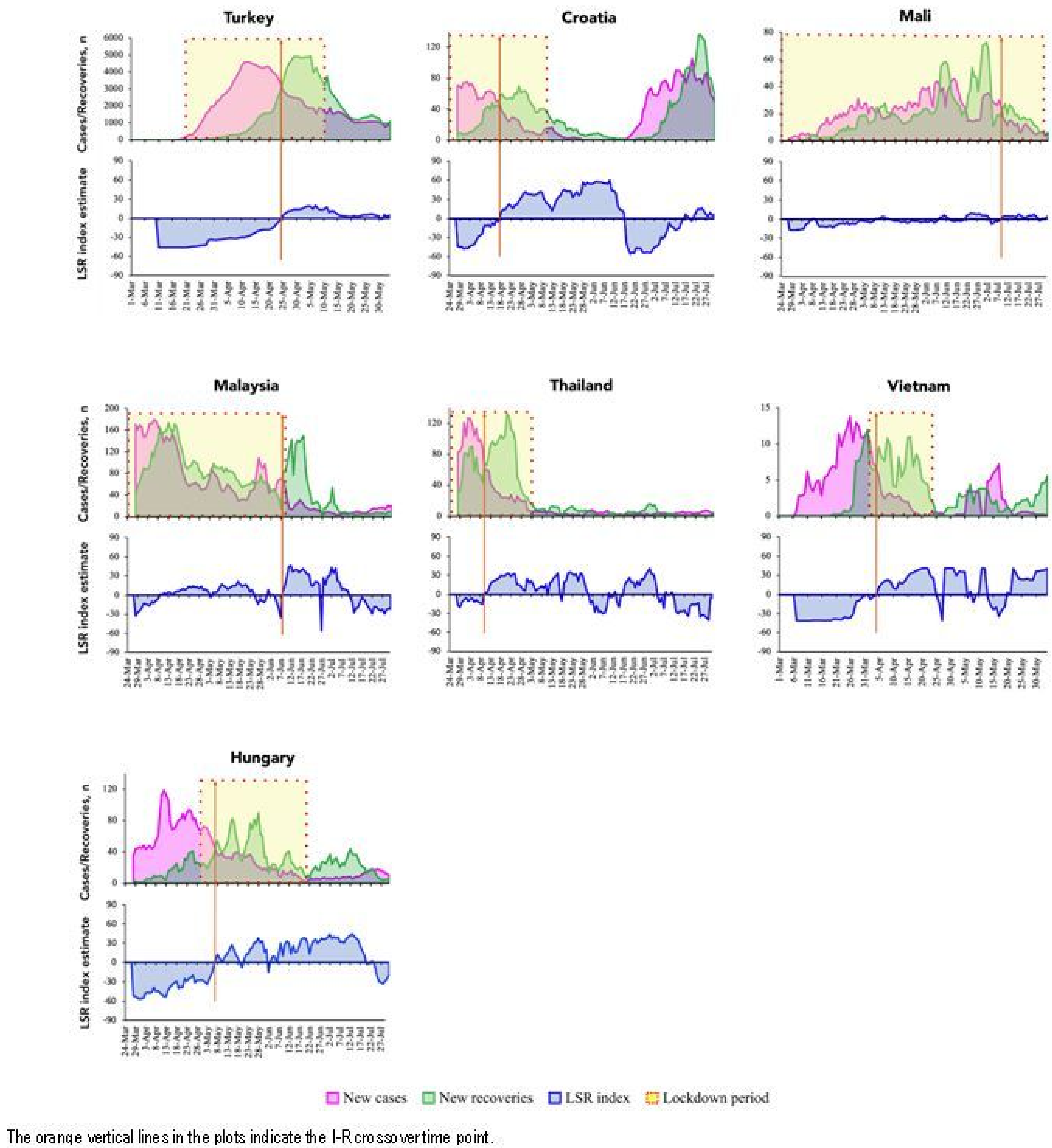
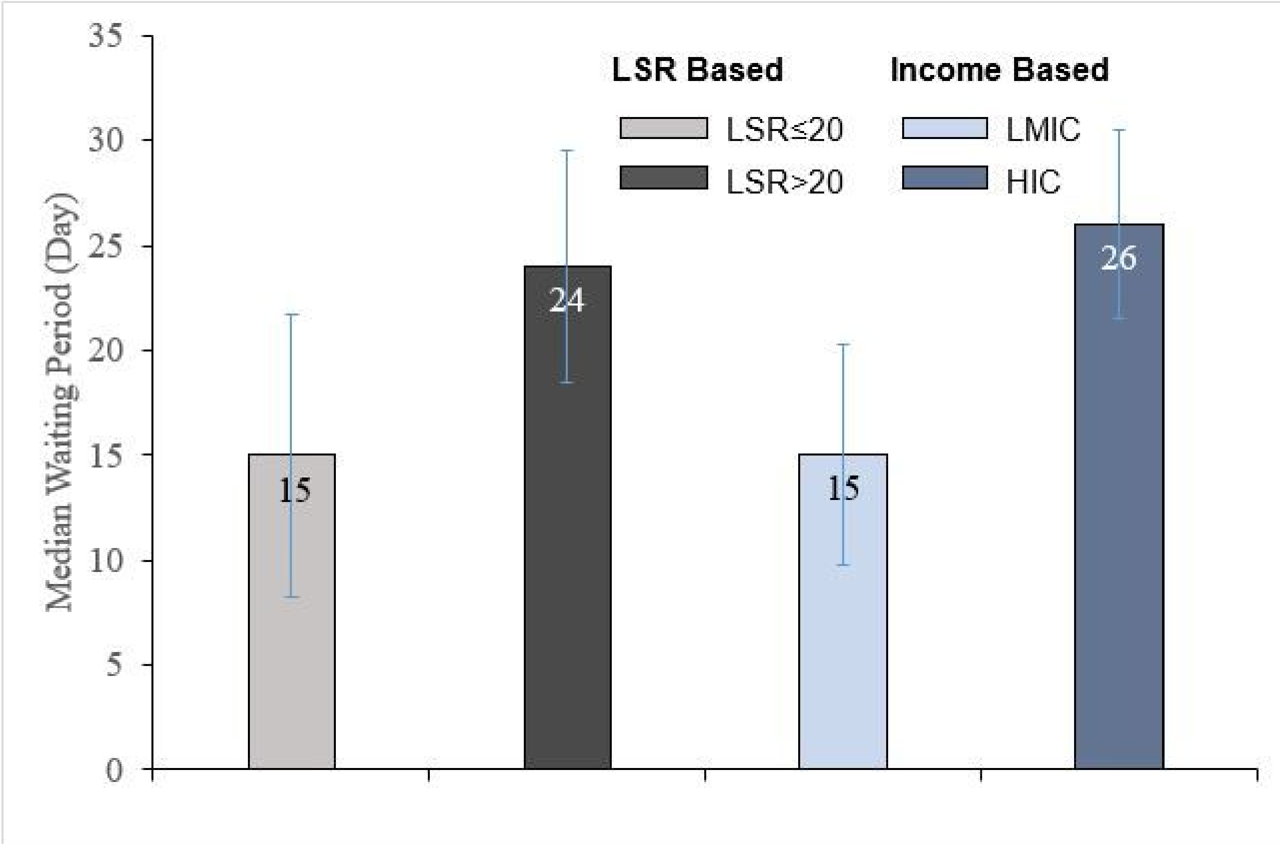


Figure 2

Infection-recovery (top panel) and the corresponding LSR index (bottom panel) trajectories in the successful low/middle-income countries



LSR, Large-scale reopening; LMIC, Low-income and middle-income countries; HIC, high Income countries.

Figure 3

Median of waiting periods by two successful country groups (HIC and LMIC) and LSR index classes (LSR>20 and LSR≤20). The vertical error bars represent inter-quartile range.

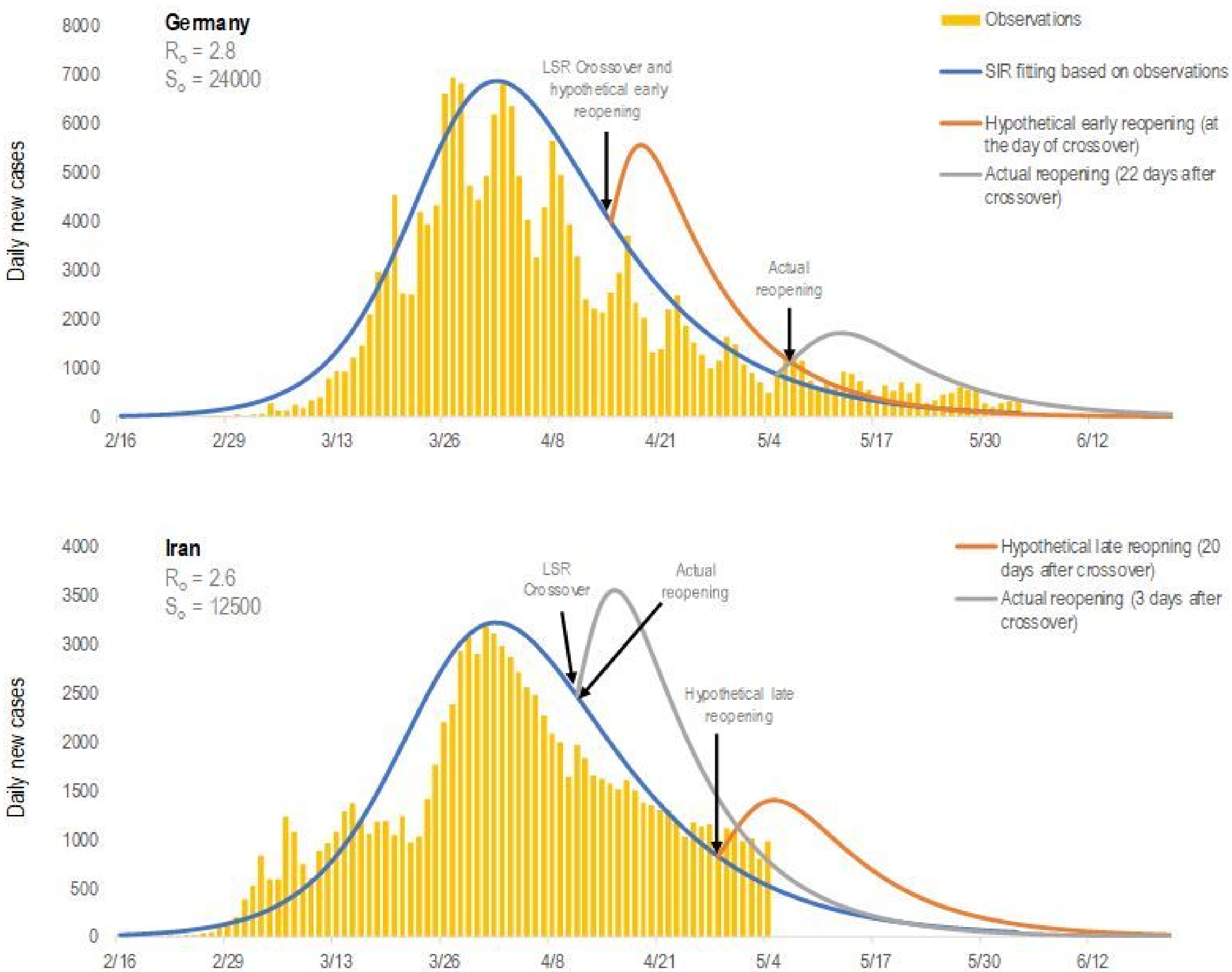


Figure 4

Impact of actual versus hypothetical index-based reopening on new daily cases

Supplementary Files

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