Supplementary appendix

Supplement to: Eng Kiong Yeoh, Ka Chun Chong, Calvin J Chiew, Vernon J Lee, Chiu Wan Ng, Hideki Hashimoto, Soon Man Kwon, Weibing Wang, Nancy Nam Sze Chau, Carrie Ho Kwan Yam, Tsz Yu Chow, Chi Tim Hung. Assessing the Impact of Non-Pharmaceutical Interventions on the Transmissibility and Severity of COVID-19 during the First Five Months in the Western Pacific Region

A1. Table S1. Sources of data, information of non-pharmaceutical interventions, and notes of data collected

Jurisdiction	Data source of the numbers of cases and deaths	Data source of the information on non-pharmaceutical interventions	Notes on data collected
Hong Kong	Department of Health Hong Kong. Data in coronavirus disease (COVID-19). 2020. https://data.gov.hk/en-data/dataset/hk-dh-chpsebcddr-novel-infectious-agent (accessed July 15, 2020).	The Government of the Hong Kong Special Administrative Region. Press releases. 2020. https://www.info.gov.hk/gia/general/today.htm (accessed July 15, 2020).	Line listing data were available. The distribution of reporting delay between illness onset and confirmation was adopted into other jurisdictions.
Singapore	Ministry of Health Singapore. Situation report. 2020. https://www.moh.gov.sg/covid-19/situation-report (accessed July 15, 2020).	Ministry of Health Singapore. Past updates on covid-19 local situation. 2020. https://www.moh.gov.sg/covid-19/past-updates (accessed July 15, 2020).	Numbers of local, imported, and dormitory cases and deaths by illness onset date and confirmation date were available.
South Korea	Ministry of Health and Welfare South Korea. Press release. 2020. http://ncov.mohw.go.kr/tcmBoardList.do?brdId=&brdGubun=&dataGubun=&ncvContSeq=&contSeq=&board_id=140&gubun=%20) (accessed July 15, 2020).	Ministry of Health and Welfare South Korea. Press release. 2020. http://ncov.mohw.go.kr/tcmBoardList.do?brdId=&brdGubun=&dataGubun=&ncvContSeq=&contSeq=&board_id=140&gubun=%20) (accessed July 15, 2020).	Numbers of local, imported, and church cases and deaths by confirmation date were available. The epidemic curves of local and imported cases adjusted with reporting delay were rebuilt.
Malaysia	Ministry of Health Malaysia. COVID-19 health systems response dashboard. 2020. http://maera.nih.gov.my/index.php/covid-19-health-systems-response (accessed July 15, 2020).	Ministry of Health Malaysia. COVID-19 health systems response dashboard. 2020. http://maera.nih.gov.my/index.php/covid-19-health-systems-response (accessed July 15, 2020).	Numbers of local, imported, and tabligh cases and deaths by confirmation date were available. Missing data in some dates were interpolated between number of cases in adjunct dates. A late confirmation of 972 cases on 19/5 in the tabligh cluster were redistributed uniformly in each of the date within the outbreak period.
Japan	Ministry of Health Labour and Welfare of Japan. Press release. 2020. https://www.mhlw.go.jp/stf/houdou/index.html (accessed July 15, 2020).	Ministry of Health Labour and Welfare of Japan. Press release. 2020. https://www.mhlw.go.jp/stf/houdou/index.html (accessed July 15, 2020). NHK (Japan Broadcasting Corporation). Time series news. 2020. https://www3.nhk.or.jp/news/special/coronavirus/chronology/ (accessed July 15, 2020).	Numbers of local and imported cases and deaths by confirmation date were available. The epidemic curves of local and imported cases adjusted with reporting delay were rebuilt.
Shanghai	Shanghai Municipal Health Commission. Outbreak notification. 2020. http://wsjkw.sh.gov.cn/yqtb/index_13.html (accessed July 30, 2020).	Shanghai Municipal Health Commission. Press release. 2020. http://wsjkw.sh.gov.cn/xwfb/index.html (accessed July 30, 2020).	Numbers of local and imported cases and deaths by confirmation date were available. The epidemic curves of local and imported cases adjusted with reporting delay were rebuilt.
Taiwan	Taiwan Center for Diseases Control. Datasets. 2020. https://data.cdc.gov.tw/en/dataset. (accessed July 15, 2020).	Ministry of Health and Welfare Taiwan. Timeline COVID-19. 2020. https://covid19.mohw.gov.tw/en/sp-timeline0-206.html (accessed July 15, 2020).	Numbers of local and imported cases and deaths by confirmation date were available. The epidemic curves of local and imported cases adjusted with reporting delay were rebuilt.

		Taiwan Centers for Disease Control. Press releases. 2020. https://www.cdc.gov.tw/En/Category/NewsPage/tov1jahKUv8RGSbvmzLwFg (accessed July 15, 2020).	

A2. Table S2. Summary of non-pharmaceutical interventions at different phases

	Intervention phase in the first epidemic	Intervention phase in the second epidemic	Relaxation phase
Hong Kong	Entry restrictions on Hubei (27/1), non-HK residents coming from Korea or having visited Korea (25/2); special work arrangements for civil servants until 2 Mar (29/1), and 14-day mandatory quarantine on people arriving Hong Kong who have been to the Mainland China (8/2), Korea (25/2), and three regions in Italy or to Iran (1/3).	Border control and quarantine measures included 14-day mandatory quarantine on people arriving Hong Kong who have been to some regions in France, Germany, Japan and Spain as well as on the entire country of Italy (14/3), 26 European countries in the Schengen Area (17/3), all overseas countries/jurisdictions (19/3), and banning entry of all non-Hong Kong residents coming from overseas countries and regions by plane (25/3). Social distancing measures included special work arrangements for civil servants (23/3), prohibition on group gathering of > 4 people in public places (29/3), and closure of businesses included six types of premises (28/3), karaoke establishments, mahjong-tin kau establishments and nightclubs (1/4), bars (3/4), beauty parlours and massage establishments (10/4).	Resume normal work arrangements for civil servants (4/5), prohibition on group gathering of >8 from >4 people in public places (5/5), reopening of entertainment facilities (7/5), most public swimming pools and barbecue sites (21/5), beaches (23/5), schools (27/5), resume operations of seven types of business premises, bars and pubs subject to compliance with more stringent requirements (7/5), and bathhouses, party rooms, clubs or nightclubs and karaoke establishments (29/5).
Singapore	Suspension of all flights between Singapore and Wuhan (23/1), banning entry of visitors with recent travel history to Hubei (29/1), mainland China (1/2), and mandatory quarantine for persons with recent travel history to Hubei (28/1).	Border control and quarantine measures included border restrictions to Daegu city and Cheongdo county, Republic of Korea (26/2), Iran, Northern Italy and Republic of Korea (4/3), Italy, France, Spain and Germany (15/3), ASEAN countries, Japan, Switzerland and United Kingdom (16/3), and banning entry of visitors from all countries (23/3), 14-day Stay-Home Notice on visitors and returning residents from all other countries (20/3). Social distancing measures included suspension of all events/ gatherings with ≥ 250 participants and separation of at least 1 metre between patrons at public venues (20/3), limited gatherings outside work and school to 10 people or fewer, closure of bars and entertainment, reduced operating capacity of malls, museums and attractions to one person per 16 sqm, suspension of all religious services and congregations, all tuition and enrichment centre classes, and canceled all events and mass gatherings (26/3), "circuit breaker", closure of workplaces/ retail, stay at home except for essential purposes, closure of all visitor attractions (7/4), full home-based learning for schools and institutes of higher learning, closure of pre-schools and student care centres (8/4), lockdown of all dormitories and mandatory SHN for migrant workers in the construction sector (21/4).	Allow home-based food businesses, confectioneries, hairdressers and laundry services to resume operations, and small group lessons for students in graduating cohorts (12/5).
Malaysia	Banning entry of visitors from Wuhan, Hubei (27/1), other areas under Chinese lockdown (7/2) and mandatory 14-day quarantine for Malaysians from China arriving in Malaysia if tested negative (21/2).	School closure (14/3), entry restrictions on foreign visitors and tourists from countries/ jurisdictions and mandatory 14-day quarantine for Malaysians arriving in Malaysia (18/3). Movement Control Order (MCO), banning all mass gathering, work from home for civil service and private sector except essential services, closure of all business premises and all indoor entertainment/ recreational facilities including swimming pools and cinemas, gyms, indoor sports venues and snooker centres (18/3).	Conditional Movement Control Order (CMCO), civil servants to work from home, staggered working hours or working in the office on alternate days (similar arrangements encouraged for the private sector and reopening of most businesses, exceptions include indoor entertainment centres remain closed) (4/5), mosque prayers allowed for limited number of attendees (15/5).

Japan	Immigrant restriction from Wuhan and surrounding district (31/1)	Border control and quarantine measures included 14 days quarantine and no public transportation use from mainland China and South Korea (6/3), designated places from overseas countries/ jurisdictions (19/3); immigrant restriction from non-resident travelers from Italy, France, Germany, and designated European countries (27/3), mainland China, UK, and USA (3/4). Social distancing measures included suspension of all school and learning (2/3), work from home with flexible working hours and split commune time (7/4).	Recommendation to re-open shops (14/5)
Shanghai	Extension of return-to-work date from Chinese New Year (CNY) and work from home until Feb 9, closure of all business premises until Feb 9, cancelation centralized meetings, collective activities and offline training until May 18, closure of indoor culture facilities, entertainment facilities and theaters, extension of return-to-school date from CNY (24/1). Mandatory 14-day quarantine for people who lived or traveled in Hubei (except Wuhan) within 14 days until Mar 18, and people who lived or traveled in Wuhan within 14 days until April 8 (27/1).	Mandatory 14-day quarantine for arriving people from all overseas countries/ jurisdictions (26/3), and reduced the number of international flights, and occupancy rate no more than 75% (29/3).	Avoid concentrated dining by canteen delivery or off-peak dining, reopening of schools (27/4), and reopening of indoor culture facilities and entertainment facilities, allow centralized meetings and collective activities (9/5).
Taiwan	Banning entry of people who resides or originally resided in Wuhan (23/1), Hubei (25/1), mandatory 14-day home quarantine for residences from China and Chinese people (26/1), postponed the opening of University and College until Feb 25 (3/2), and schools until Feb 25 (11/2).	Border control and quarantine interventions included banning entry of foreigners (19/3), mandatory home quarantine for inbound travelers who developed symptoms from US and East Asia between 8 - 18/3, and be tested for retrospective investigation (21/3), quarantine for those travelers to Wuhan within 14 days and exhibited a fever or symptoms of upper respiratory tract infections with testing positive (1/5), and inbound travelers should stay at the dedicated quarantine hotels (4/5). Social distancing measures included suspension of indoor events that are attended by > 100 people and outdoor gatherings that are attended by > 500 people (25/3), host and hostess clubs and ballrooms (9/4), crowd control measures at public places (10/4).	Applications for the lodging sites in Yushan National Park, Taroko National Park and Shei-Pa National Park will be accepted (7/5).
South Korea	Banning entry of foreigners with travel history to Hubei, China and special entry procedure for arriving persons from Mainland China (includes body temperature screening, medical questionnaire, and installing 'Self-quarantine safety protection App') for both non-residents and residents (4/2), and school closure (24/2).	Special entry procedure for persons arriving from all overseas countries/ jurisdictions (includes body temperature screening, medical questionnaire, and installing 'Self-quarantine safety protection App') for both non-residents and residents (19/3), and mandatory 14-day quarantine for persons arriving from all overseas countries/ jurisdictions (1/4). Social distancing measure included comprehensively crack down on facilities and businesses posing relevant risks with on-site inspection (22/3).	Relieved recommendation of closing indoor sports facilities, recreational facilities and religious facilities; and re-opening schools, starting with high school grade 3 students (20/4).

A3. Estimation of piecewise reproduction number and delay-adjusted case-fatality ratio

Estimation of piecewise reproduction number (R_t)

We employed the method proposed by Thompson and colleagues[1] to estimate the instantaneous reproduction number ($R_{m,t}$) in a jurisdiction *m*. Besides the local cases, this method also accounts the transmission potential from the imported cases as adopted in elsewhere.[2] By assuming a prior distribution of $R_{m,t}$ follows a gamma distribution (with shape=k, scale=θ), the posterior mean of $R_{m,t}$ is

$$\frac{k+\sum_{s=t-\tau}^{t} h_L(m,s)}{\sum_{s=t-\tau}^{t}\sum_{i=1}^{s} w_i\left[h_L(m,t-i)+h_I(m,t-i)\right]+\frac{1}{\theta}}$$

with a posterior variance of

$$\frac{k+\sum_{s=t-\tau}^{t} h_L(m,s)}{\left\{\sum_{s=t-\tau}^{t}\sum_{i=1}^{s} w_i\left[h_L(m,t-i)+h_I(m,t-i)\right]+\frac{1}{\theta}\right\}^2}$$

where $h_L(\cdot)$ and $h_I(\cdot)$ denote the number of local and imported cases, respectively at their illness onset date in jurisdiction *m,* and τ is the moving average smoothing width which is assumed to be 7 days.[3] w_i is a discretized probability mass function of the serial interval of COVID-19 and the serial interval was truncated within a maximum of 14 days.

To adjust for the delay between illness onset date and confirmation date of the infected cases, we reconstructed the epidemic curves using the following equation:

$$h^{onset}(m,t)=\sum_u \phi(u)h^{confirm}(m,t+u)$$

where $h^{onset}(m,t)$ and $h^{confirm}(m,t)$ are the number of cases with illness onset at day *t* and the number of cases confirmed on day *t* in jurisdiction *m* respectively, and $\phi(u)$ is the discretized probability mass function of delay duration *U* which was assumed to follow a gamma distribution. The reconstruction of the number of cases were done for each of the

time series of imported cases and local cases. The reporting delay was truncated within a maximum of 28 days.

To obtain the estimated piecewise R_t for summarizing the impact of control measures in different periods, we employed a similar form of Bayesian regression model from Flaxman and colleagues.[4] By assuming $R_{m,t}$ as an exponential function of a baseline parameter ($R_{m,0}$) and an indicator variable ($X_{m,i}$) for different periods in jurisdiction m, we have the following equation

$$R_{m,t} = R_{m,0} \exp\left(-\sum_i \alpha_{m,i} X_{m,i}\right)$$

where $\alpha_{m,i}$ characterized the variation of transmission in different periods. Based on a similar setting from Flaxman and colleagues[4], we assumed $\alpha_{m,i}$ and $R_{m,0}$ follow a gamma distribution (shape=0.5, scale=1) and a normal distribution (mean=2, SD=2), respectively. We sampled the posterior mean estimate of the piecewise $R_{m,t}$ with corresponding 95% credible intervals by using Hamiltonian Monte Carlo sampling. Four MCMC chains each with 5,000 warm-ups and 5,000 iterations for posterior draws were run.

Estimation of delay-adjusted case-fatality ratio (dCFR)

Crude CFR at day t jurisdiction m was estimated by simply dividing the cumulative number of deaths by the cumulative number of cases on their date of confirmation:

$$CFR(m,t) = \frac{\sum_t d^{confirm}(m,t)}{\sum_t h^{confirm}(m,t)}$$

where $d^{confirm}(m,t)$ is the number of confirmed deaths at day t. To adjust for the reporting delay between illness onset and death, we used a similar convolution equation:

$$d^{onset}(m,t) = \sum_u \pi(u) d^{confirm}(m,t+u)$$

where $d^{onset}(m,t)$ is the number of cases at their illness onset date t who finally die, and $\pi(u)$ is the discretized probability mass function of delay duration U which was assumed

to follow a gamma distribution. By assuming a mean delay of 16 and SD of 6 days[5,6] between illness onset and death, the dCFR is

$$dCFR(m,t) = \frac{\sum_t d^{onset}(m,t)}{\sum_t h^{onset}(m,t)}$$

Poisson-to-binomial approximation was used to estimate the confidence intervals of the CFRs.

Reference

1 Thompson RN, Stockwin JE, van Gaalen RD, et al. Improved inference of time-varying reproduction numbers during infectious disease outbreaks. *Epidemics* 2019; **29**: 100356.

2 Chong KC, Cheng W, Zhao S, et al. Monitoring disease transmissibility of 2019 novel coronavirus disease in Zhejiang, China. *Int J Infect Dis* 2020; **96**: 128–30.

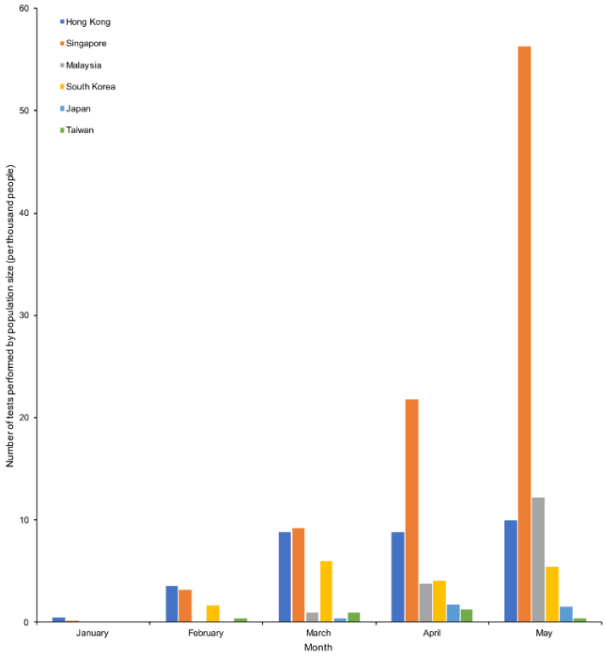
3 Cori A, Ferguson NM, Fraser C, Cauchemez S. A new framework and software to estimate time-varying reproduction numbers during epidemics. *Am J Epidemiol* 2013; **178**: 1505–12.

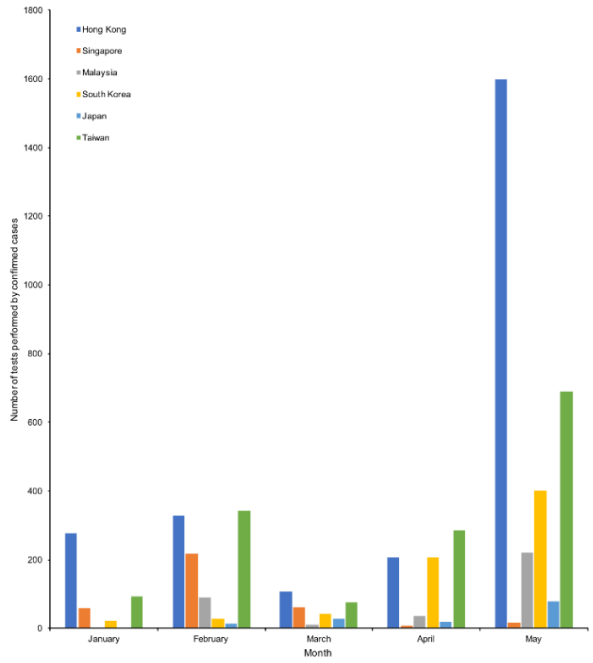
4 Flaxman S, Mishra S, Gandy A, et al. Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe. *Nature* 2020; published online June 8. https://doi.org/10.1038/s41586-020-2405-7

5 Khalili M, Karamouzian M, Nasiri N, Javadi S, Mirzazadeh A, Sharifi H. Epidemiological characteristics of COVID-19: a systematic review and meta-analysis. *Epidemiol Infect* 2020; **148**: e130.

6 Chen T, Wu D, Chen H, *et al.* Clinical characteristics of 113 deceased patients with coronavirus disease 2019: Retrospective study. *BMJ* 2020; **368**: m1091.

A4. Figure S1. Monthly total numbers of testing for COVID-19 (A) per thousand population and (B) per confirmed cases by jurisdiction





Sources: The statistics of monthly total number of testing COVID-19 were obtained from Our World In Data (https://ourworldindata.org/) for Malaysia and Taiwan, from Department of Health for Hong Kong, from Ministry of Health, Labour and Welfare for Japan, from Ministry of Health of Singapore for Singapore, and from Ministry of Health and Welfare of South Korea for South Korea.