



Time: 21:00 p.m. (Beijing Time), March 3, 2020

## Daily Brief on International Epidemic of COVID-19

Data: Based on the outbreak data up to March 2.

Countries concerned: Iran, Italy, Spain, France, Germany, South Korea, Japan, Singapore, Malaysia, Thailand and Vietnam. Diamond Princess was analyzed separately. We expect to start US analysis in coming data.

**Method:** Apply the vSIR model developed by our team to calculate the effective reproduction number  $R$  for each country. See medRxiv posting for its application on China: <https://www.medrxiv.org/content/10.1101/2020.02.17.20024257v1>

See also [www.songxichen.com](http://www.songxichen.com) for COVID-19 project.

A special term: **the effective reproduction number ( $R$ ) is the average number of infections made by an infected while being infectious. Only when  $R$  is less than 1, the outbreak begins to slow down and gradually comes to an end.**  $R$  is the most determining factor for the internal dynamic of an outbreak. Our early study on COVID-19 in 30 provinces of China shows that  $R$  is an effective leading index and has good forecasting power for COVID-19 outbreak in China under the vSIR model framework.

**Results:** (i) The effective reproduction number  $R$  at 10.5 and 14 days infectious duration (Fig1) and the infection loading statistics in the past 7 days, and Risk Rating for each country (Table 1).

(ii) Time series plots of the 14-day  $R$  of Korea, Japan, Iran and Italy along with four China provinces (including Hubei) to gain information on the epidemic stages of Korea, Japan, Iran and Italy relative to the provinces of China. See Fig 2.

(iii) Future projection of infected subpopulation size for Korea and Japan. See Fig 3.

**Key Finding:** For the first time, Japan's 14-day  $R$  is lower than 1. Although it is not statistically significantly less than 1, it is a good sign on the slowing down of the epidemic there. Our prediction now is that the outbreak in Japan would be gone by the end of June and Tokyo Olympics would not be affected based with 95% prediction confidence. We hope that the Korea's epidemic would end sooner (now projected over a time interval from June to September). Our prediction is that China's epidemic would

end by the end of June with the provinces other than Hubei clearly up the infected stocks by the end of April.

### **Other Findings**

1. Iran's 14-day reproduction number  $R$  is 7.38 with 1,260 confirmed cases and increasing exponentially. Iran's risk level is F, which is the highest rating in our report.
2. The 14-day  $R$  in Italy is 4.2, and there are 1,835 confirmed cases and the risk rating is E, one level lower than Iran. The trends in the dynamics of Iran and Italy's reproduction number ( $R$ ) are similar to that of Hubei province (Wuhan is the capital city of the province) in late January to early February.
3. Korea's  $R$  is currently at 2.71, with up to 4,753 confirmed cases and is rated as E risk category. Korea's 14-day  $R$  has declined and leveled around 3.5 since it went over 9 on February 14. It is evident that the contagious force as results of the collective infections of the church group has been released. The pattern of its infection dynamic is similar to that of China's Zhejiang province in early February. Under the removal (including recover and death) rate being 0.1, we predict that Korea's number of infected cases will reach its peak between March 10 and March 20, 2020, and it would decline to zero between July 4 and September 2. The estimated number of cumulative infected persons will be between 17,657 and 55,106 as shown in Figure 3.1.
4. The 14-day  $R$  in Japan (excluding Diamond Princess) is 0.93 but it is not significantly less than 1 at the 5% statistical significance. We have downgraded the risk level of Japan to C from D. Japan's 14-day  $R$  was higher than 3 in the mid-February and then declined with some fluctuations. The number of new and cumulative confirmed cases in Japan in the past 7 days has gradually declined. The epidemic in Japan is very similar to the dynamics in Shanghai in early February and the risk is relatively low. Under the scenario of 0.1 removal rate, we predict that the number of infected cases in Japan would be zero between April 28 and June 30, 2020, and the estimated number of cumulative infected persons would be between 313 and 810 as shown in Figure 3.2. Therefore, it is most likely that the Olympics would not be affected as far as the epidemic of Japan is concerned. We hope that the Korea's epidemic would end sooner, which would provide a better surrounding to the event. Our prediction is China's epidemic would be gone by the end of June.

5. Effective reproduction numbers of Spain, France, and Germany are 6.07, 5.41, and 4.52 respectively, all significantly greater than 1, suggesting these countries are in the early exponential growth phase. However, as these three countries are still in their early stage of the epidemic, the R numbers may be over-estimated, in particular, as many of the confirmed cases are the imported cases from Italy.
6. The 14-day R in Malaysia is 2.64 with a recurrent outbreak. There's been no new cases occurred between February 15 to 26 while 7 new confirmed cases since February 27 with 11 confirmed cases in total. The overall epidemic situation is relatively not severe with a risk rating of C. The 14-day period R in Singapore is also greater than 1, but it is not significantly greater than 1 at 5%. With 32 existing confirmed cases in total, the risk rating of Singapore is C, indicating the overall epidemic situation is relatively moderate.
7. The risk rating for Thailand and Diamond Princess is B. All Diamond Princess personnel have disembarked on March 2 and the number of existing confirmed cases is 700. In Vietnam, there have been no new cases emerging for 4 consecutive days in with a risk rating of A, the best in these countries.
8. As the international epidemic is gaining momentum, there is an increasing risk of "back-flow" epidemic to China. There have been cumulatively 13 foreign imported cases from Italy, Iran and England in China since February 29 to March 3. Among them, there are 8 in Zhejiang, 2 in Ningxia, 2 in Beijing and 1 in Shenzhen.

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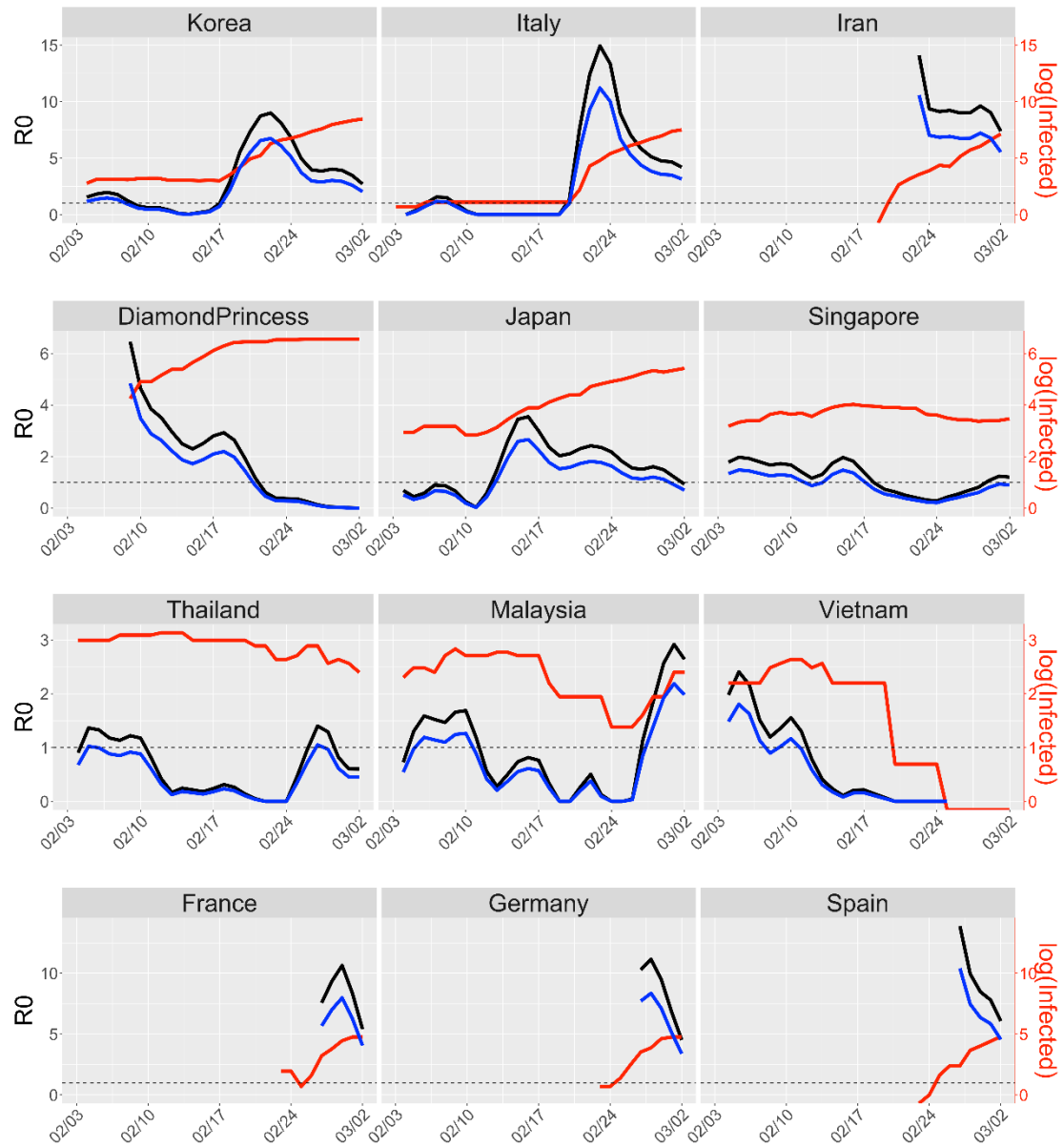
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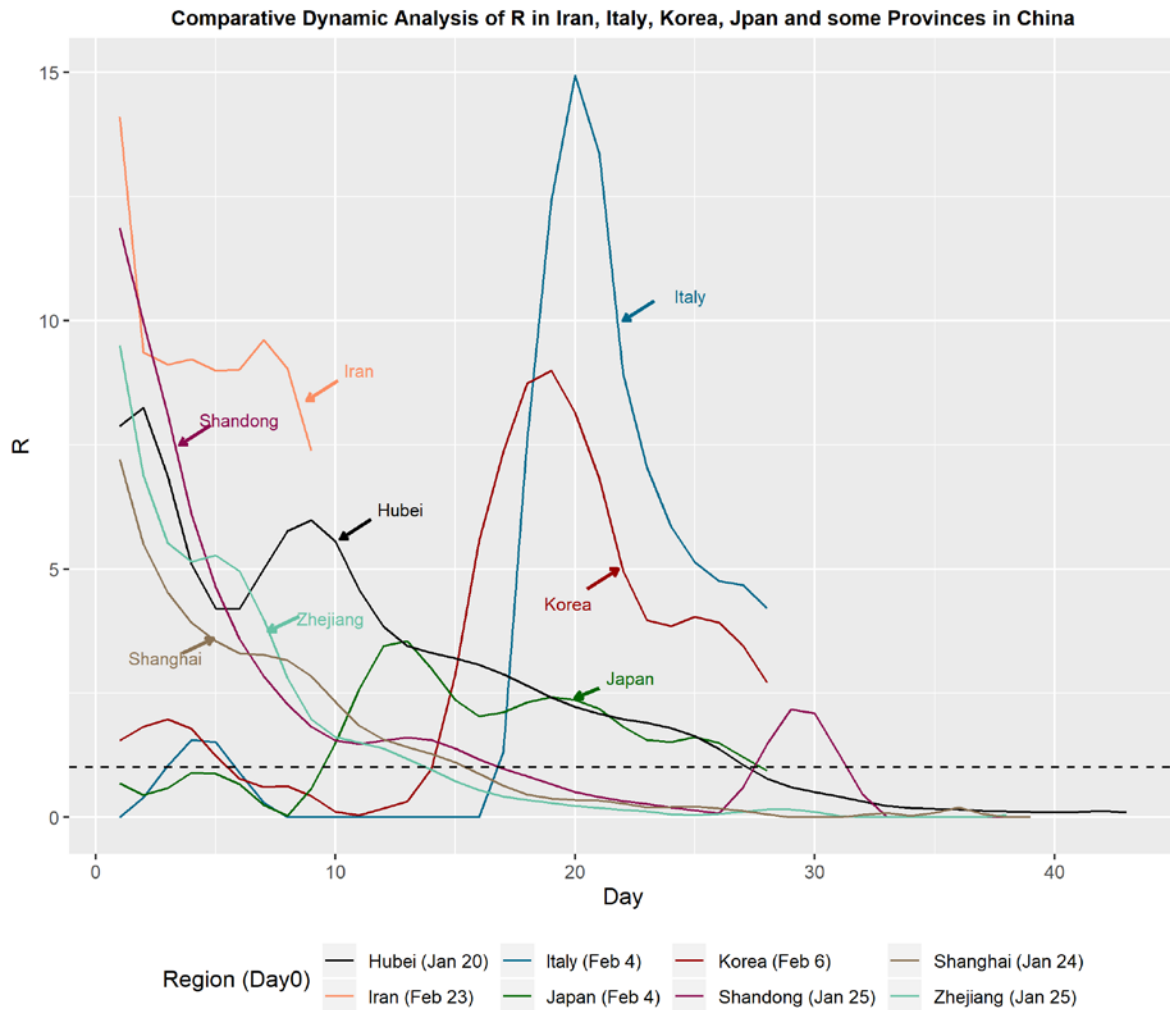
**Table 1: Effective Reproduction Number (R) up to March 2, 2020 and Statistics on Confirmed Cases.** The calculation of R is based on the assumptions that the infection duration is one and a half weeks (10.5 days) and two weeks (14 days). ++ indicates that R is greater than 1 at the at the 5% statistical significance. -- indicates that R is significantly less than 1 at 5%. [x] represents the number of consecutive days for which R has been significantly less than 1 at 5%. Data in ( ) is the number of confirmed cases up to the previous day. The risk level of the epidemic in each region is derived from the value of R and the number of new cases, ordering from A to F with increasing severity.

Rank	Country	R (10.5 days)	R (14 days)	Number of Existing Cases up to March 2	Number of New Confirmed Cases in the Past 7 Days	Number of New Existing Cases in the Past 7 Days	Risk Level
1	Iran	5.54++	7.38++	1260(749)	1440(935)	1211(714)	F
2	Spain	4.55++	6.07++	121(82)	120(82)	120(82)	D
3	France	4.05++	5.41++	116(116)	118(118)	109(109)	D
4	German	3.39++	4.52++	116(116)	114(114)	114(114)	D
5	Italy	3.15++	4.2++	1835(1577)	1807(1570)	1614(1456)	E
6	Korea	2.03++	2.71++	4753(4160)	3919(3449)	3886(3422)	E
7	Malaysia	1.98++	2.64++	11(11)	7(7)	7(4)	C
8	Singapore	0.9	1.2	32(30)	16(13)	-5(-8)	B
9	Japan	0.7--[1]	0.93	227(211)	115(110)	91(87)	C
10	Thailand	0.45--[2]	0.6--[2]	11(13)	8(7)	-3(-1)	B
11	Diamond Princess	0--[10]	0--[10]	700(699)	11(10)	8(7)	B
12	Vietnam	End	End	0(0)	0(0)	-2(-2)	A

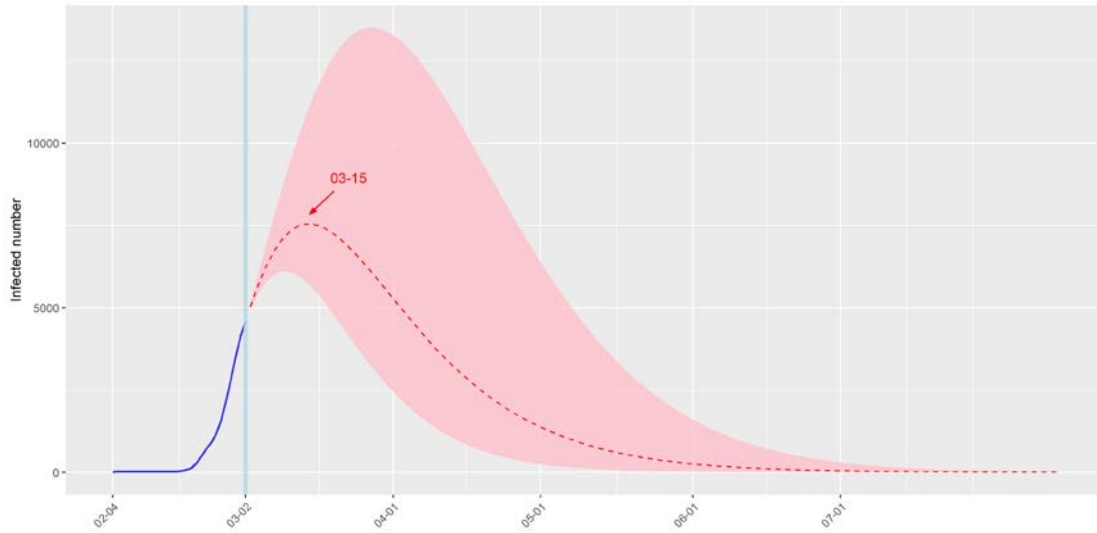
**The turning point of an outbreak:** due to the random fluctuations and reporting errors in the data, we suggest that the turning point of an outbreak in a region is confirmed only when the timespan for which R has been significantly lower than 1 is equal to or larger than the average duration from the infection date to the clinical confirmation date ( we suggest using 7 days based on Chinese data for COVID-19). That is, if the R based on the 14-day infectious duration has been significantly (at 5% level) lower than 1 for 7 consecutive days, it may be declared that the turning point has been reached.



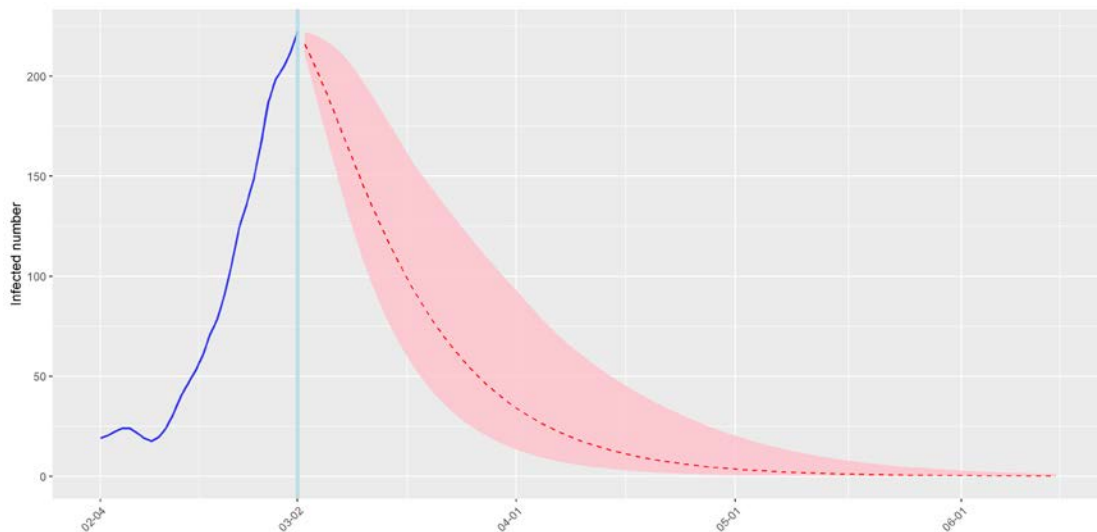
**Figure 1.** Time series plots of estimated effective reproduction numbers  $R$  and the **logarithm of infected cases** (red) up to March 2, 2020. Two  $R$ s are given based on **10.5-day infectious duration** (blue) and 14-day duration (black). The critical threshold level  $R=1$  is the horizontal dashed line.



**Figure 2. Effective Reproduction Number (R) in Iran, Italy, South Korea, Japan, and some comparative provinces in China Up to March 2, 2020, Based on a 14-day Infectious duration.** Time 0 is the fifth day of the outbreak which are given in the legend. The critical threshold  $R=1$  is marked by the horizontal dashed line. Only when  $R$  is less than 1, the outbreak begin to decline and gradually come to an end.



**Figure 3.1. Projected Numbers of Confirmed Cases in South Korea.** Observed number of infected persons (left blue solid line) and predicted number of existing infected persons (right red dashed line) with the 95% projection interval (pink region). Date with the most recent data (vertical cyan line) was March 2, 2020. Under the assumption of removal rate ( $\gamma$ ) equal to 0.1, we predict that the number of existing cases would peak between March 10 and March 20, and then decrease to zero between July 4 and September 2. The number of cumulative infected persons is estimated to be between 17,657 and 55,106 by the 95% prediction interval.



**Figure 3.2. Projected Number of Confirmed Cases in Japan.** Numbers of infected persons (left blue solid line) and predicted number of existing infected persons (right red dashed line) with the 95% projection interval (pink region). Date with the most recent data (vertical cyan line) was March 2, 2020. Under the assumption of removal rate ( $\gamma$ ) equal to 0.1, we predict that the number of existing cases would peak on March 2, and further decline zero between April 28 and June 30. The number of cumulative infected persons is estimated to be between 313 and 810 by the 95% prediction interval.