北京大学 PEKING UNIVERSITY IOWA STATE UNIVERSITY

Time: 21:00 p.m. (Beijing Time), March 6, 2020

Daily Brief on International Epidemic Situation of COVID-19

Data: Based on the outbreak data up to March 5

13 Countries concerned: Iran, Italy, Spain, France, Germany, South Korea, Japan, US, UK， Singapore, Malaysia, Thailand and Vietnam. Diamond Princess was analyzed separately.

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's: https://www.medrxiv.org/content/10.1101/2020.02.17.20024257v1

A special term: the effective reproduction number (R) is the average number of infections made by an infected person 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 (Figure1), 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's provinces (including Hubei) to gain information on the epidemic stages of Korea, Japan, Iran and Italy relative to the provinces of China (Figure 2).

(iii) Future projection of infected subpopulation size for South Korea and Japan (Figure 3).

Key Finding:

Japan's 14-day R rebounded to 1.33 on March 5 after dropped below 1 on March 3, due to an increase in the number of new confirmed cases in cities like Tokyo, Aichi-ken, etc. Within the 95% confidence interval, we expect the outbreak in Japan to end between May and early September, two months later than our previous prediction. This will also have an impact on the Olympic Games, indicating the uncertainty of the development of the epidemic in Japan. In recent days, R in South Korea has dropped

significantly, and we expect the end of epidemic there will be brought forward to early June based on our model with data up to March 5. Under the premise of effective control of imported cases, our prediction is that China's epidemic will end in June with provinces other than Hubei clearing up the infected stocks by the end of April.

Other Findings:

1. The 14-day reproduction number R in Iran is 6.34 with 3,710 existing confirmed cases increasing exponentially, rated as F which is the highest risk level in our report. From February 24 to 29, the 14-day R in Iran remained higher than 9. Then, the value of R gradually decreased, the trend of which was similar with that of Hubei province (Wuhan is the capital city of the province) in late January. In the past seven days, 4,502 new cases have been confirmed in Iran, while the number of cured cases has increased significantly from 49 on February 28 to 913 on March 5, leading to an increase of 3,540 cases in existing confirmed cases in the past week.

2. The 14-day R in Italy is 3.11 with 3,475 confirmed cases, rated as E which is one risk level lower than Iran. Italy's 14-day period R was higher than 10 from February 22 to February 24, after which it declined rapidly to 5 on February 28; then the value of R kept declining moderately to 3.11 on March 5. The trend in the dynamics of Italy's reproduction number R is similar with that of Hubei in early February. In Italy, there have been 3,205 new cases confirmed in the last seven days, with an increase in the number of cured cases from 46 on February 28 to 276 on March 5.

3. Korea's 14-day R kept dropping to 1.35, with up to 6,201 confirmed cases and is rated as E risk level. Korea's 14-day R has been declining since it went over 9 on February 21 and leveled around 3.5 from February 26 to March 1, after which it further declined to 1.35 on March 5. It is evident that the contagious force as results of the collective infections of the Shincheoji church group has been released. The pattern of its infection dynamic is similar with that of China's Zhejiang province in early February. Under the premise of removal (including recover and death) rate being 0.1, we predict that Korea's number of infected cases would reach its peak in a few days, and afterwards it would decline to zero between June 3 and June 10. The estimated number of cumulative infected persons will be between 7,325 and 9,860 as shown in Figure 3.1.

4. The 14-day R in Japan (excluding Diamond Princess) bounded back to 1.33 with a recurrent outbreak since the situation slightly eased off in the end of February and is rated as C risk level. During the week from February 25 to March 2, an average of 16 new cases were confirmed daily in Japan. The value of 14-day R dropped below 1 for the first time on March 2, indicating the risk of outbreak was

once mitigated. However, there have been accumulatively 86 new cases confirmed from March 3 to March 5 in cities like Tokyo, Aichi-ken, etc. and therefore the value of R rose to 1.33. Within the 95% confidence interval, we would postpone the predicted end of the epidemic in Japan from the end of June to May 9 to September 6, therefore the Olympics would be affected. The number of existing cases in Japan is expected to reach the peak in a few days, and the cumulative number of infections by the end of the outbreak is expected to be between 481 and 1,352 (Fig 3.2). Up to March 5, a total number of 7,476 PCR tests for COVID-19 have been conducted in Japan. With the further expansion of detection scope in the future, the trend of the epidemic remains to be seen.

5. The 14-day R in the United States is up to 3.77 with 215 confirmed cases. The trend of the dynamics of the reproduction number R in USA is very similar to that of Japan in mid-February. Up to March 5, 19 states have reported confirmed cases, with more than 20 confirmed cases in Washington State, California State and New York State, which are therefore considered to be the epicenters of the outbreak. No confirmed cases have been reported in central USA.

6. Effective reproduction numbers of UK, Spain, France, and Germany are significantly greater than 1, suggesting these countries are in the early exponential growth phase, with a risk rating of D. In the UK, the 14-day R is up to 5.18 and the number of existing confirmed cases has exceeded 100 for the first time. There are 404, 335 and 226 existing cases respectively in France, Germany and Spain, with the 14-day R declining steadily to 4.39, 3.62 and 3.04 respectively. However, as these three countries are still in their early stage of the epidemic, the R numbers may be over-estimated particularly as many of the confirmed cases are the imported cases from Italy.

7. The 14-day R in Malaysia is 3.77 with a recurrent outbreak, and the risk rating was upgraded from C to D. There has been no new cases occurred between February 15 to 26 while 28 new confirmed cases from February 28 to March 6, leading to an increase in the value of R from lower than 1 to 4.56, further resulting an upgrade in the risk rating from C to D. The 14-day period R in Singapore is also greater than 1, but it is not significantly greater than 1 at 5%. With 33 existing confirmed cases in total, the risk rating of Singapore is C, indicating the overall epidemic situation is relatively moderate.

8. The risk rating for Thailand and Diamond Princess is B. The trend of the 14-day R of Diamond Princess is quite similar with that of Beijing in late January. All Diamond Princess passengers and crew members have disembarked on March 3 and the number of existing confirmed cases is 700. In Vietnam, there have been

no new cases emerging from February 25 to March 5 with a risk rating of A, which is the best in these countries.

9. As the international epidemic is gaining momentum, there is an increasing risk of "back-flow" epidemic to China. There have been cumulatively 40 foreign imported cases from Italy, Iran, England and Spain in China since February 29 to March 6. Among them, there are 12 in Gansu, 10 in Zhejiang, 7 in Beijing, 4 in Ningxia, 2 in Shenzhen, 1 in Shanghai and 4 in unknown places.

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See also www.songxichen.com for COVID-19 project.

Table 1: Effective Reproduction Number (R) Up to March 5, 2020 and Statistics of 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 5% statistical significance. -- indicates that R is significantly less than 1 at 5% statistical significance. [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 or risk level 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 3	Number of New Confirmed Cases in the Past 7 Days	Number of New Existing Cases in the Past 7 Days	Risk Level
1	Iran	4.76++	6.34++	3710(2278)	4502(2783)	3540(2207)	F
2	Italy	2.33++	3.11++	3475(2706)	3205(2619)	2884(2251)	E
3	Korea	1.01++	1.35++	6201(5689)	4262(4171)	4214(4128)	E
4	England	3.88++	5.18++	107(77)	101	100	D
5	France	3.29++	4.39++	404(241)	385	379	D
6	US	2.82++	3.77++	215(139)	172	158	D
7	Germany	2.72++	3.62++	335(226)	301	301	D
8	Spain	2.28++	3.04++	226(162)	216	215	D
9	Malaysia	3.42++	4.56++	28(28)	27(28)	23(24)	D(C)
10	Japan	1	1.33++	308(279)	146(142)	120(115)	C
11	Singapore	0.91	1.21	33(33)	19(19)	2(2)	C
12	Thailand	0.64	0.85	15(11)	7(3)	-3(-7)	B
13	Diamond Princess	0--[13]	0--[13]	690(700)	-9(1)	-10(-1)	B
14	Vietnam	End	End	0(0)	0(0)	0(0)	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.

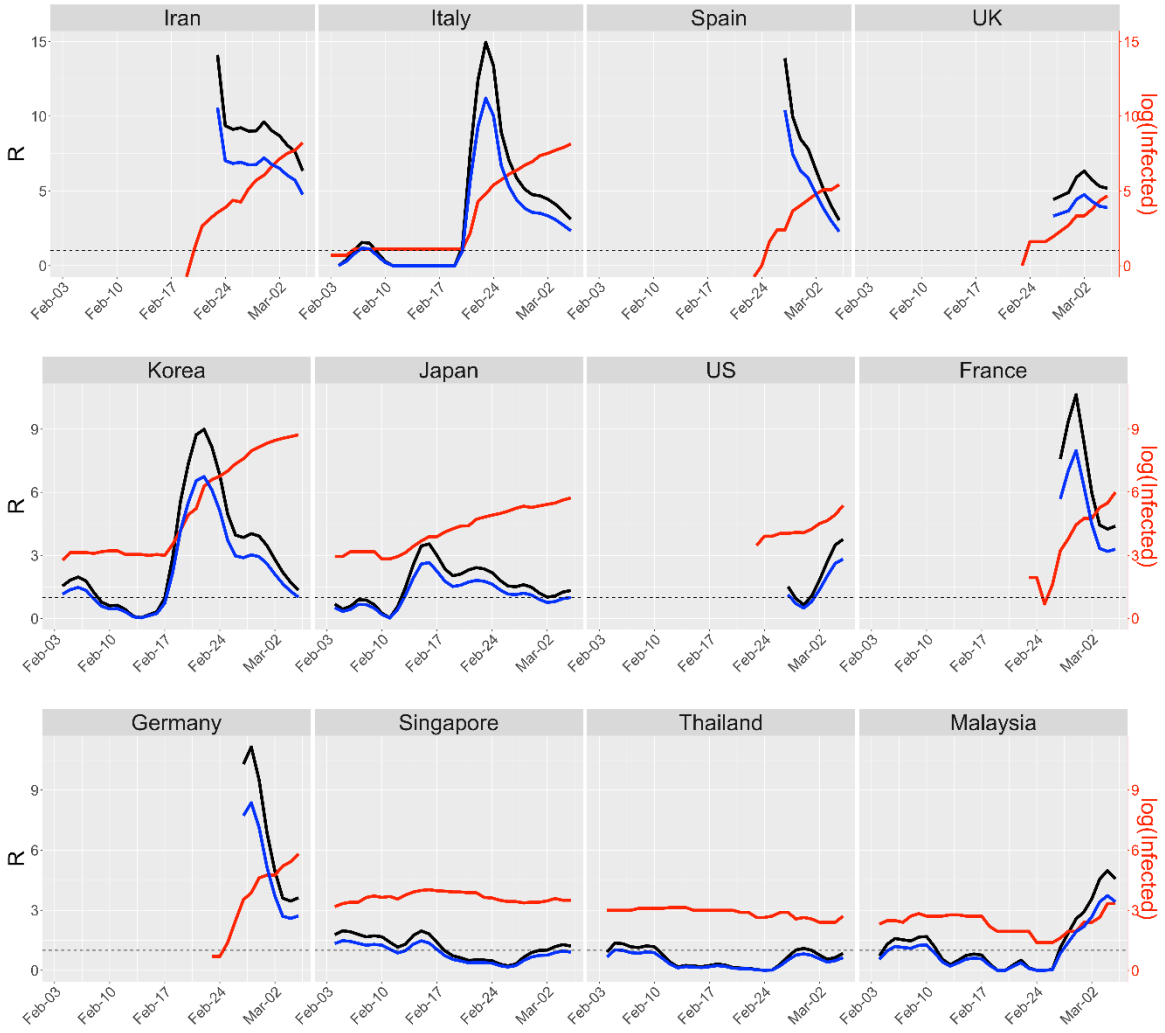

Figure 1. Time Series Plots of Estimated Effective Reproduction Numbers R and the Logarithm of Infected Cases (red) Up to March 5, 2020. Two Rs are given based on 10.5-day infectious duration (blue) and **14-day infectious duration (black)**. The critical threshold level R=1 is the horizontal dashed line.

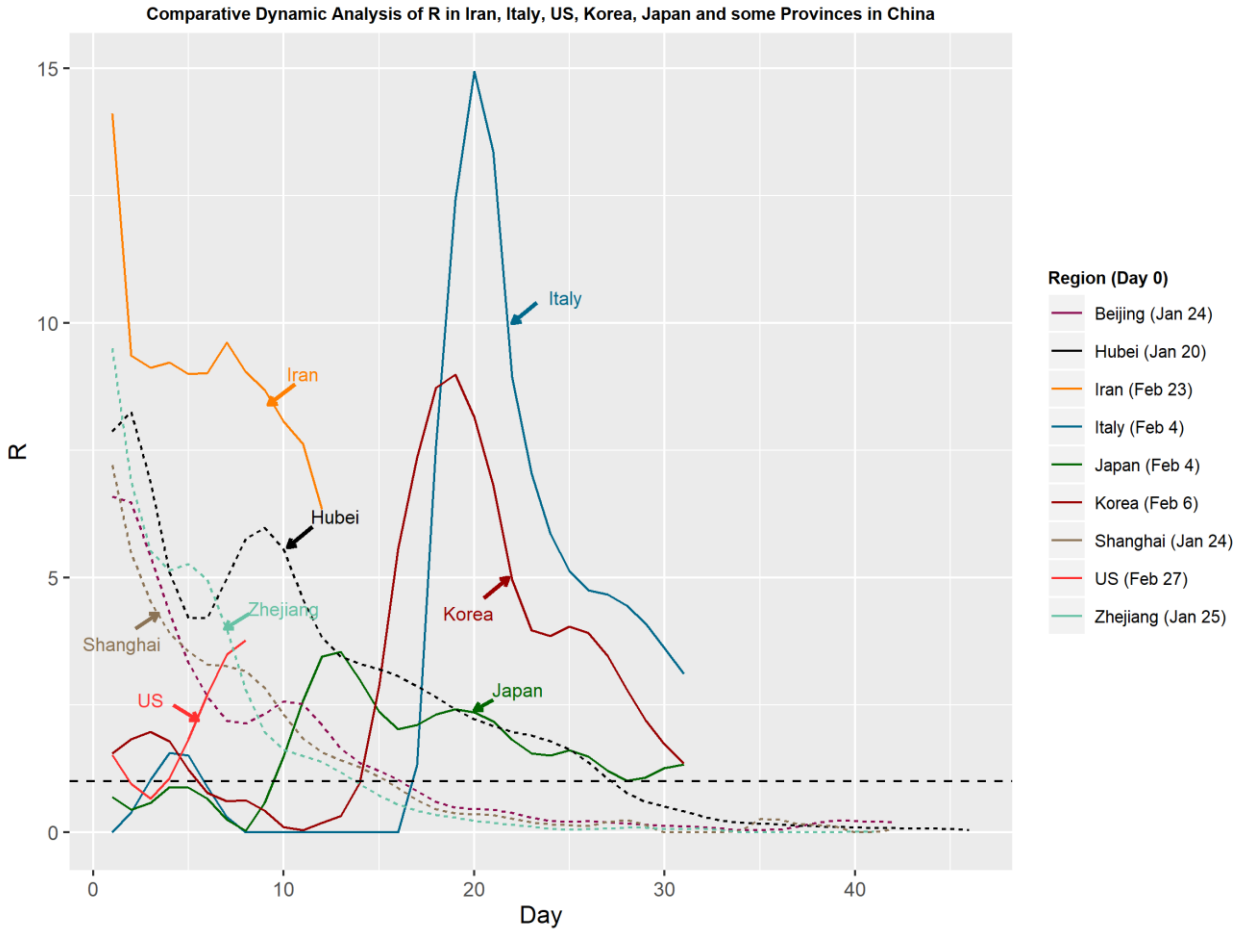

Figure 2. Effective Reproduction Number (R) in Iran, Italy, South Korea, Japan, and Some Comparative Provinces in China up to March 5, 2020, Based on a 14-day Infectious Duration. Day 0 is the fifth day since the outbreak which are given in the legend. Dashed line refers to provinces within China while solid line refers to countries worldwide. The critical threshold R=1 is marked by the horizontal dashed line. Only when R is less than 1, the outbreak begins to decline and gradually come to an end.

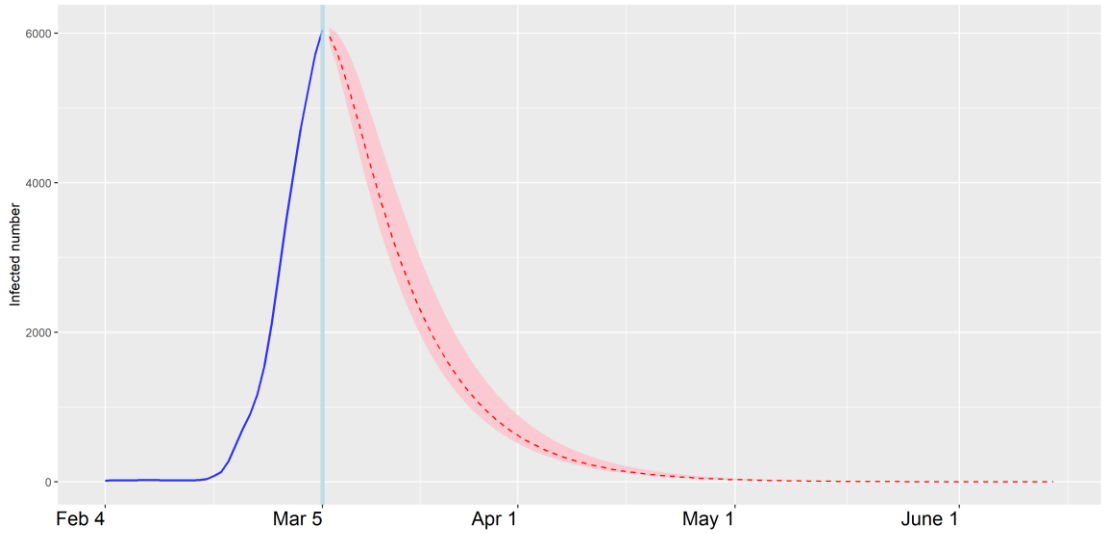

Figure 3.1. Forecast of Number of Confirmed Cases in South Korea. Observed number of infected persons (left blue solid line) and predicted number of existing infected persons (right red dashed line). 95% confidence interval (pink region). Date with the most recent data (vertical cyan line), which is March 5, 2020. Under the assumption of removal rate (γ) equal to 0.1, we predict that the number of existing cases has already reached the peak on March 5, and would further decrease to zero between June 3 and June 10. The number of cumulative infected persons is estimated to be between 7,325 to 9,860.

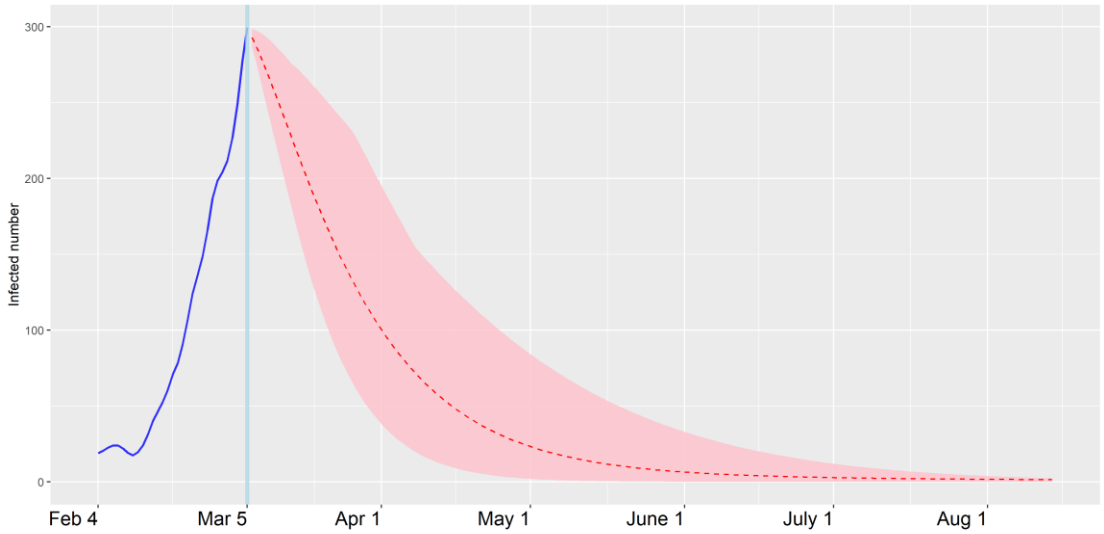

Figure 3.2. Forecast of Number of Confirmed Cases in Japan. Observed number of infected persons (left blue solid line) and predicted number of existing infected persons (right red dashed line). 95% confidence interval (pink region). Date with the most recent data (vertical cyan line), which is March 5, 2020. Under the assumption of removal rate(γ) equal to 0.1, we predict that the number of existing cases would reach the peak between March 5 and March 6, and further decline zero between May 9 and September 6. The number of cumulative infected persons is estimated to be between 481 and 1,352.