



Time: 23:00 p.m. (Beijing Time), March 16, 2020

Daily Brief on International Epidemic Situation of COVID-19

Data: Based on the outbreak data up to March 15

21 Countries concerned: (1) Asia: Iran, South Korea, Japan (excluding Diamond Princess), Malaysia, Singapore, Thailand and Vietnam; (2) Europe: Italy, Spain, France, Germany, UK, Holland, Switzerland, Belgium, Austria, Denmark, Norway and Sweden; (3) North America: US and Canada.

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>

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 (Figure1), 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 international areas along with Hubei and Beijing in China to gain information on the epidemic stages (Figure 2-1 and 2-2).

Key Finding: (i) Asia: **The 14-day R of Korea has been significantly lower than 1 at 5% level for 7 days, implying the turning point has been achieved.** The epidemic in Japan, Singapore and Malaysia came to a state of stalemate resulting from passive countermeasures adopted.

(ii) Europe: Italy's 14-day R declined more slowly to 2.7, which is similar with that of Hubei in early February. The 14-day R of Spain and France has been declining slowly to 4.9 and 2.93 separately, while that of Germany rebounded to 3.97. Lack of efficient countermeasures in the UK leads to an increase in 14-day R since March 9 to

3.8. Besides, there're over 1,000 confirmed cases in Holland, Norway, Sweden and Switzerland with the 14-day R greater than 1, which suggests these countries are still in the stage of exponential increasing.

(iii) North America: The 14-day R of the US rebounded to 4.06 indicating the epidemic is at the stage of exponential increasing, rated at E. Canada's R value increased to 3.7 with over 300 infections in 10 provinces.

Other Findings:

1. The 14-day R of South Korea further dropped to 0.16, which has been significantly less than 1 for 7 consecutive days up to March 15, indicating **the turning point has been achieved**. Meanwhile the number of infections has been declining with fluctuations due to the decrease in new confirmed cases and increase in recovery, indicating the countermeasures in Korea are quite effective.
2. In the United States, the 14-day R is 4.06, with 3,624 existing confirmed cases which is 964 more than the previous day, rated at E. The R value in the US rebounded after declining to 3.5, indicating the epidemic is still increasing exponentially. There're over 400 cases in Washington state, New York state and California, while Virginia is the only one without positive cases. The 14-day R in Canada increased to 3.7 with 338 existing confirmed cases which is 90 more than the previous day, rated at B. Ten provinces in Canada have reported positive cases, among which there're over 140 cases in Ontario and more than 50 cases in British Columbia and Albert separately.
3. In Italy, the 14-day R is 2.7 with 20,794 infections, rated as F which is the highest level in our report. There have been more than 3,000 positive diagnoses per day in last 2 days, indicating the epidemic is still spreading quickly. The number of the recovered increased to 2,335 on March 15 from 743 a week ago. The 14-day R leveled around 3.5 for 6 days until March 10 and then declined slightly to 2.7 on Mar 15, **which is similar with that of Hubei (Wuhan is the capital city of the province) in early February**. The epidemic situation in northern Italy has worsened with 10,043 infections in Lombardy and over 1,000 cases in other 4 regions nearby.
4. Iran's 14-day R is 2.42, which has maintained around 2.5 for days. With 9,142 confirmed cases, Iran is still in an exponential growth stage, rated as F which is the highest level in our report. There've been 8,425 new cases in the past seven days, with a total of 4,996 cured as of March 15. Iran's R value is similar with that of Hubei in mid-February. The epidemic situation may be underestimated in Iran due to insufficient tests.

5. Japan's 14-day R gradually declined to 1.1 after increasing to 1.25, rated as C, with 637 existing cases and an increase of 7 cases in a single day. Japan's PCR detection capacity is less than 7,000 per day, far behind that of South Korea, which is more than 20,000, inferring a larger number of actual confirmed cases. Whether the Olympic Games can be held as scheduled remains to be seen, and Chairman Xi's visit will also be affected.
6. Spain, France, and Germany are in the stage of exponential increase, with over 5,000 existing confirmed cases increasing exponentially, rated at E. The epidemic in Spain is quite severe with 7,876 infections. The 14-day R in Spain declined to 4.92 on March 15 from 5.92 on March 11. The dynamics of R in Spain is comparable with that of Hubei in late January and the value of R is close to that of Italy at the end of February, indicating the possibility of further outbreak. The epidemic in France and Germany came to stalemate, whose 14-day R values are comparable to that of Hubei in early February and that of Italy in early March. The R value in France declined to 2.83 from 3.63 in a week, while that of Germany increase to 3.97 on March 15 due to the bounce since March 12.
7. The 14-day R value in the UK increased to 3.8 on March 15 due to the bounce since March 9, which had been decreasing rapidly in earlier stage. With 1,319 infections, there's a recurrent growing trend of the outbreak due to lack of effective countermeasures in UK. There're over 1,000 cases in Switzerland, Sweden, Holland and Norway, and over 850 cases in Belgium, Austria and Denmark. The 14-day R of those countries with large infected stocks are between 2 and 4, implying the risk of further outbreak.
8. The epidemic in Singapore and Malaysia is still at a stalemate without signals of recurrence. The 14-day R in Malaysia increased to 4.95, indicating a grim picture. Singapore has adopted strict immigration control and relatively loose domestic control. Due to increasing backflow of domestic and alien workers, there's serious import risk in Singapore. Eleven out of 17 cases reported on March 16 are imported cases, mainly from Europe and the US. Domestic cases are mainly caused by clusters, which requires more powerful control policies.
9. Thailand's 14-day R continued to rise to 3.2 since March 3, implying a slightly recurrent outbreak, rated at B. The same happened in Vietnam. There are 41 new cases from March 7 to March 15 after the infected cases were cleared on Feb 25.

Summary: Europe and America gradually became the epidemic centers worldwide, as the epidemic in Korea achieved the turning point and the outbreak of China came under control. Italy and France come to a state of stalemate, while there're recurrent outbreaks in the UK and Germany. In North America, the epidemic is spreading quickly, where the number of infections is increasing exponentially. Based on domestic experience of the transmission pattern of the coronavirus, imported risk is going to be one of the primary concerns in a long time. For one thing, the government should pay more attention to dynamics in epidemic centers such as Europe and the US and adopt more powerful countermeasures to prevent imported cases. For the other, it is worth noticing that the variety in the intensity of control policies and public awareness further increase the complexity.

Song Xi Chen Research Team

Guanghua School of Management and Center for Statistical Science

Peking University

Team Members: Haoxuan Sun, Han Yan, Yaxuan Huang, Xinyu Zhang, Ziheng Zhang, Yuqing Wang, Mengdi Shi, Jia Gu, Haobo Qi, Xiangyu Zheng, Yuru Zhu, Li Chen from Peking University; Yumou Qiu of Iowa State University, Zheng Xu of Wright State University, Shan Yang of Merck & Co; Ying Wang of University of Auckland.

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

Table 1: Effective Reproduction Number (R) up to March 15, 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 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 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 15	Number of New Confirmed Cases in the Past 7 Days	Number of New Existing Cases in the Past 7 Days	Risk Level
1	Iran	2.03++	2.7++	20794(17863)	17563(15387)	14407(12802)	F
2	Iran	1.82++	2.42++	9142(8624)	8425(8115)	4904(4615)	F
3	Spain	3.69++	4.92++	7876(5627)	8155(5877)	7306(5123)	E
4	US	3.04++	4.06++	3624(2660)	3128(2281)	3083(2244)	E
5	Germany	2.98++	3.97++	6043(4843)	4958(4179)	4945(4170)	E
6	France	2.2++	2.93++	5260(4373)	4297(3551)	4165(3452)	E
7	Korea	0.12--[10]	0.16--[7]	7024(7253)	758(1028)	-235(277)	E
8	Austria	3++	4++	853(648)	758(576)	751(569)	D
9	Belgium	2.94++	3.92++	882(882)	717(777)	714(774)	D
11	UK	2.85++	3.8++	1319(1101)	1166(977)	1123(947)	D
12	Switzerland	2.46++	3.29++	1547(1175)	1335(979)	1323(969)	D
10	Holland	2.09++	2.78++	1115(947)	947(831)	928(820)	D
13	Norway	2.05++	2.74++	1074(1043)	908(899)	905(896)	D
14	Sweden	1.79++	2.39++	1015(953)	862(824)	854(816)	D
15	Denmark	1.21++	1.61	860(826)	829(804)	826(804)	D
16	Malaysia	3.71++	4.95++	386(396)	335(345)	316(336)	C
17	Singapore	1.26++	1.67++	121(107)	88(82)	65(59)	C
18	Japan	0.83--[1]	1.1	637(630)	324(324)	196(220)	C
19	Canada	2.77++	3.7++	338(248)	277(193)	276(192)	B
20	Thailand	2.4++	3.2++	78(78)	64(64)	60(60)	B

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.

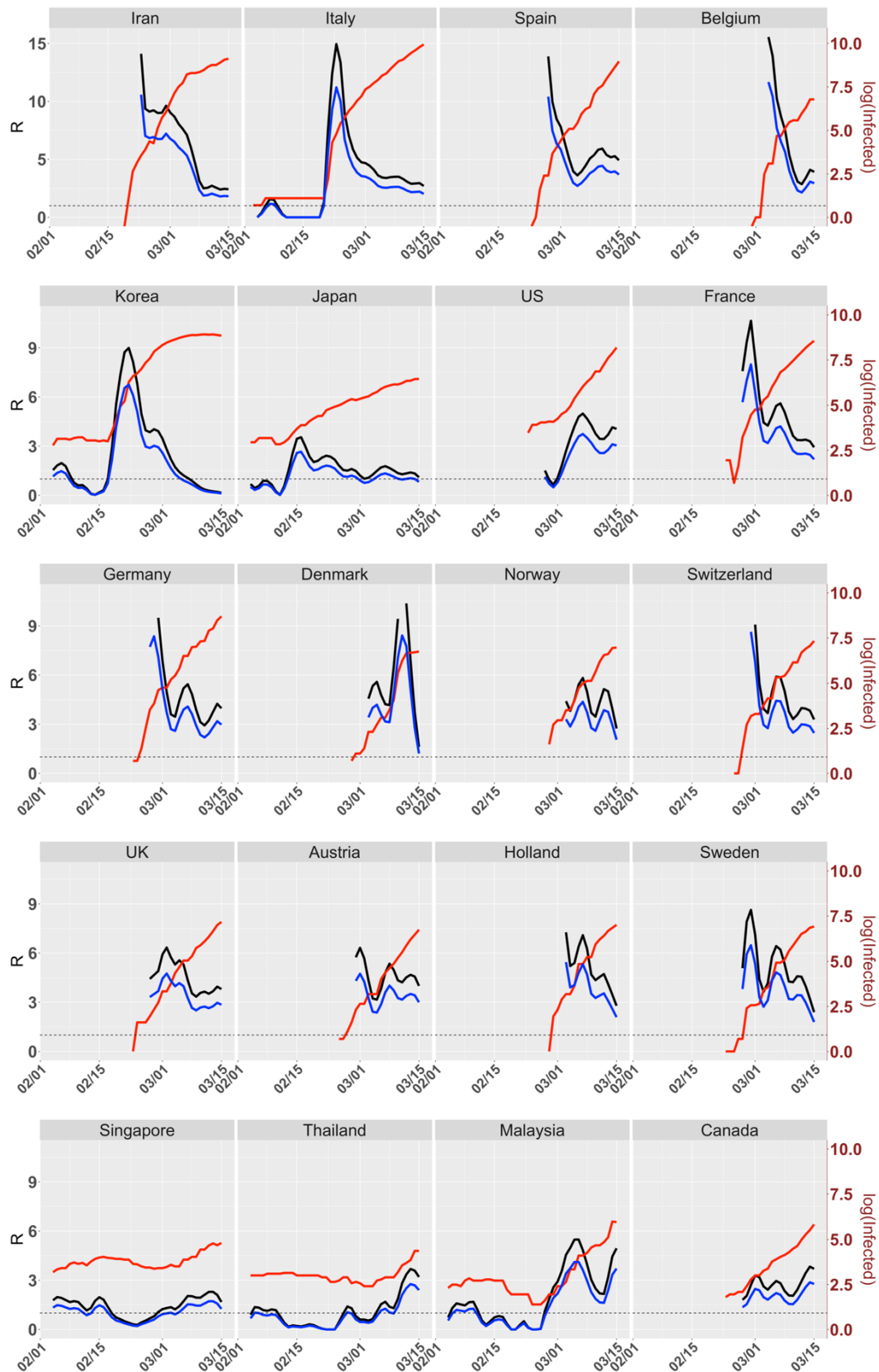


Figure 1. Time series plots of estimated effective reproduction numbers R and the **logarithm of infected cases (red)** up to March 15, 2020. Two R s are given based on **10.5-day infectious duration (blue)** and **14-day duration (black)**. The critical threshold level $R=1$ is the horizontal dashed line.

Comparative Dynamic Analysis of R in Iran, US, Canada, Korea, Japan, Singapore and some Provinces in China

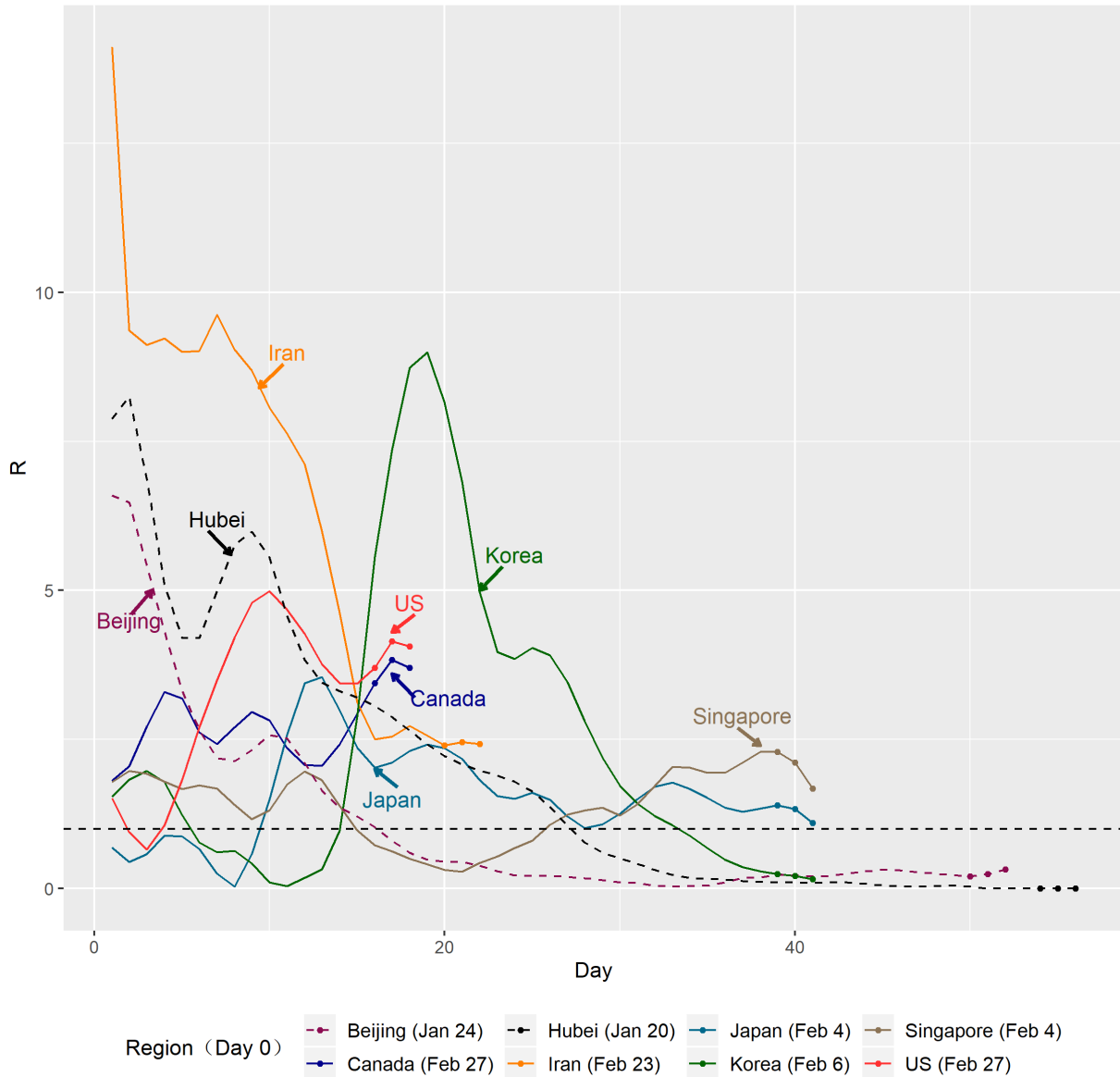


Figure 2.1. Effective Reproduction Number (R) in Canada, Iran, US, Korea, Japan, Singapore and some Comparative Provinces in China up to March 15, 2020, based on a 14-day Infectious Duration. Day 0 is the fifth day since the outbreak which are given in the legend. Points at the end of the line refer to the value of R of recent 3 days. 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.

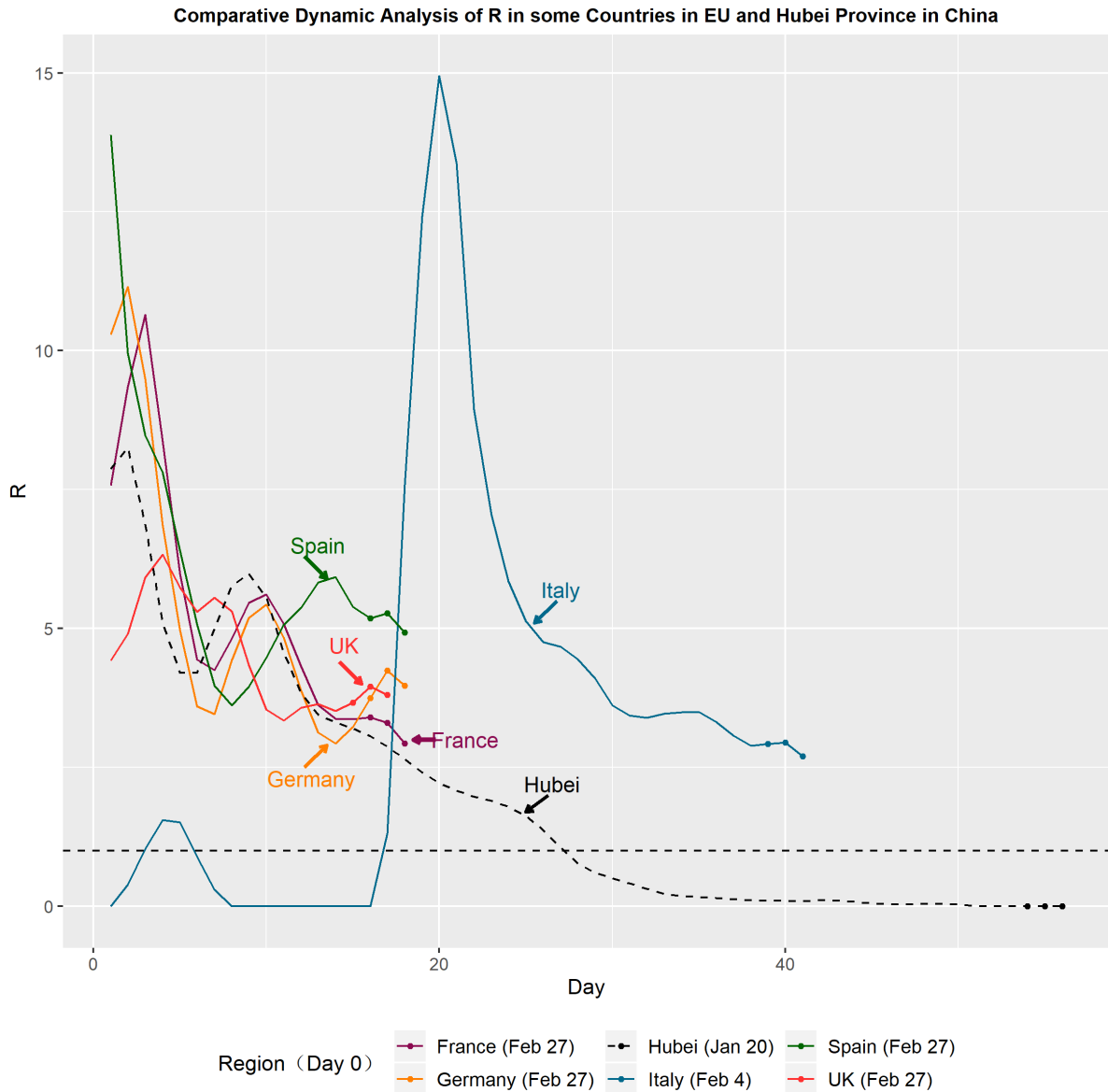


Figure 2.2. Effective Reproduction Number (R) in EU and Hubei Province in China up to March 15, 2020, based on a 14-day Infectious Duration. Day 0 is the fifth day since the outbreak which are given in the legend. Points at the end of the line refer to the value of R of recent 3 days. The critical threshold $R=1$ 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.