Time: 15 p.m. (Beijing Time), March 29, 2020

Daily Brief on International Epidemic Situation of COVID-19

Pandemic is happening. Countries need to take more drastic measures.

Data: Based on the outbreak data up to 20 p.m. (Beijing Time), March 28, 2020

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

Abstract: Recently, the epidemic situation in Europe and the United States has significantly deteriorated. The United States has risen to the epicenter worldwide, with more than 10,000 daily confirmed cases for five consecutive days. The 12 European countries continue to show exponential growth and high mortality rates. The Korean epidemic has improved overall, but for other Asian countries the epidemic situations are still severe. Preventing imported cases is still an critical issue for China. In the next seven days, the number of new infections in the 20 countries will be about 500,000. As the mandatory ability of European and American governments are more limited than that of the Chinese government, the risk of further worsening of the pandemic is very high. At present, if countries do not take further measures to block pathways of infection, the total final number of infections may reach more than 10 million, which will have an important impact on World's and China's economy and international security.

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 dynamics 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 the 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, projected number of overall cases and new cases in next seven days (new), 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) North America: The 14-day R value in the United States (hereinafter referred to as the 14-day R value) reached a peak of 17.5 on March 17 and is currently down to 6.45. The average R value in the past 10 days was 10.53, indicating a great infectious power, resulting in a 10-fold increase in the cumulative number of infections to over 10k people in 10 days. We estimate 91k undocumented cases that are currently undiagnosed. Because R is high at 6.45 and the infection base is large, the U.S. outbreak will continue to deteriorate exponentially. Based on the current reproductive power and removal rate, the U.S. epidemic is expected to end by the end of 2020, and the number of infected people will eventually reach 1 to 2 million. The risk rating of U.S. is F.

(ii) Europe: Most European countries have similar patterns of epidemic infection to Italy, with a lag of one week. The R peak value of the 12 countries is 45.45 on average, and Belgium, which has the lowest peak, is as high as 16, which is very rare, indicating that the strong infectivity of coronavirus. The average R value in 12 countries is 3.37, with a total of 245,000 confirmed cases. At present, the highest R, 6.42, is in the United Kingdom (13.7k currently infected cases), other countries like Belgium 6.21 (8.4k infections), Austria 4.65 (7.4k infections), and France 3.87 (25k infections). We estimate that there are currently 120,000 undocumented cases in 12 European countries, accounting for 49% of currently infected cases. All European countries are in the exponential growth stage. In contrast, the epidemic situation in the three Nordic countries (Sweden, Norway, Denmark) is relatively optimistic in terms of infectivity, confirmed cases and undocumented cases, which may result from the narrowing scope of detection leading to underestimation. Based on current data, we expect that the epidemic in Italy will end in September to October 2020 (that is, all infected cases are cleared), with the number of total confirmed cases eventually reaching 200,000. Spain

is expected to end the epidemic by the end of 2020 to early 2021, with about 0.5 to 1 million final confirmed cases.

(iii) Asia: South Korea's R-value has fallen below 1 for 19 consecutive days, and the inflection point of the epidemic was confirmed on March 24, making South Korea the only country in 20 countries who has declining epidemic. It is expected that the epidemic will end in August to September 2020 and the cumulative cases will be more than 10,000. Japan's R-value has picked up again, maintaining above 1 for five consecutive days, which means the epidemic has rebounded. The number of total cases is expected to be between 2,000 and 13,000. The epidemic situation in Singapore, Malaysia, and Thailand is still at stalemate, with the R value still greater than 1, and the epidemic situation has not been controlled. Among them, there are nearly 2,000 cases in Malaysia and 1,000 in Thailand, both of which deserve China's vigilance. Iran ’s R value has fallen from a peak of 47 at the end of February, and has recently risen to 3.13 (21.2k infections). The epidemic situation is still severe.

Other Findings：

1. The 14-day R value in the United States has dropped to 6.45, with 104.8k cumulative cases. There are 102.2k currently infected cases, with an increase of nearly 20k in a single day. It is estimated that there are more than 90k undocumented cases, and about 200k new cases in the next 7 days. There will be more than 300k people by then, and the epidemic is expected to end by the end of 2020. The number of total cases will reach one million, rated as the highest level F. The outbreak in the United States continues to spread, with more than 50k confirmed cases in New York and more than 1k in other 18 states. The R value in Canada has recently dropped to 5.21, with 4,499 active cases and a single-day increase of 713. The epidemic is in a rapid development stage, and the rating has been upgraded to D.

2. The R value in Italy is 1.79, with 86.5k cumulative cases, 66.4k currently infections, an estimated undocumented case of 28.9k people, and over 40k new cases in the next 7 days. By the end of October, the number of cumulative infected cases will reach about 200k, with the highest risk level of F. Since the end of February, the R value in Italy has fallen rapidly from more than 20 to 1.79 on March 27, which is similar to that of Hubei Province in mid-February, with the mortality rate climbing to 10.56% and the cure rate to 12.66%. There are more than 20k currently infected cases and more than 5k deaths in Lombardy, the center of epidemic.

3. The Spanish epidemic has further deteriorated, with an R value of 3.86 and a cumulative cases of 72.2k people, with the risk rating F. It is estimated that the number of undocumented cases is more than 40k, and the number of newly confirmed cases in the next 7 days will be about 80k. The number of total confirmed cases will eventually reach 500k, or even exceed 1 million. The mortality rate climbed to 7.88% and the cure rate rose to 12.96%. The R-value has rebounded to more than 20 since early March and was currently down to 3.86 on March 27. Spain will overtake Italy in the next few days as the country with the worst epidemic in Europe.

4. The R values in France and Germany during the 14-day period were 3.87 and 3.06 respectively, which are similar to those in Hubei in mid-February. It is expected that each country will have about 40k new cases in the next 7 days, with a risk rating of E. The French R value entered the plateau period in late March and remained at about 4.5. It has slowly decreased to 3.87 in recent days. There were about 33k cumulative cases, and the cure rate and mortality rate has increased to 15.5% and 5.3% respectively. There are 25.3k active cases and an estimated 20k undocumented cases. It is expected that the outbreak will continue at least until the end of 2020, and the number of infected people will reach more than 700k. The German R value dropped rapidly from more than 16 in early March to 3.06 on March 27. The number of currently infected cases exceeded 40k, the cure rate was 14.14%, and the mortality rate was only 0.66%. A total of nearly 50k people have been diagnosed and the number of undocumented cases is about 28k. It is expected that the epidemic will end in October to November, 2020, and the number of cumulative infections will eventually be between 200k and 300k.

5. Britain ’s 14-day R value rebounded to 6.42. It is expected that the number of new cases will exceed 30k in the next 7 days, and the risk rating will be upgraded from D to E. As of March 27, there were 14,k confirmed cases in the UK, with nearly 3k new cases in a single day. It is estimated that the number of undocumented cases is 13k and the mortality rate is 5.2%. Based on the current infectious power and cure rate, most of the British and Belgian nationals will be infected, so no predictions on the number of final infections are given in Table 1. Both countries would attain the herd immunity, unfortunately.

6. Iran ’s 14-day R-value rose back to 3.13, with a risk rating of E. There are 21.2k confirmed cases, a total of 12k cured, and 2.5k deaths. It is estimated that the number of cumulative infections by the end of the epidemic will be between 45k and 660k.

7. South Korea ’s 14-day R value is 0.26, which has been below 1 for 19 consecutive days. The epidemic situation has reached its inflection point on March 24. The number of active cases is declining, with 4,523 current infections. The epidemic situation is expected to end in August to September, 2020, and the total number of infections will reach 10k.

8. Japan ’s 14-day R value is 1.28, with 1,104 currently infected cases, 49 new cases in a single day, and a estimation of 325 undocumented cases, the risk rating is C. It is expected that about 300 to 600 new cases will be added in the coming week, and the number of total confirmed cases will be between 10k and 12k people by the end of the epidemic. Japan's detection capability has gradually improved, but it is still less than 10k cases per day, which is lower than South Korea's over 30k, indicating that the number of actual infections may be even higher. The Tokyo Olympics has been confirmed to be postponed.

9. Malaysia's 14-day R value fell to 1.65. Singapore's R value has recently dropped to 1.53, but is facing a very high import risk. The importers are mainly Singapore residents and Singapore workers. The Singapore government has once again raised the level of prevention and control, while the effectiveness needs further observation. Thailand's 14-day R value fell to 2.22, with a risk rating of C.

The above analysis is just for reference. We will update the international epidemic situation and report in time.

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, 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; Editor: Xiaolu Hu.

See also www.songxichen.com for more on the COVID-19 project.

Table 1. Effective Reproduction Number (R) on March 28, 2020, the numbers of infectious, imputed undiagnosed, and other counting statistics in 1000 and prediction for the next seven day's new infection, the ending time and final size of the epidemics in 1000. The R is based 14 days infection duration and ++ (--) indicates that R is greater (less) than 1 at the 5% statistical significance and [x] represents the number of consecutive days for which R has been significantly less than 1 at 5%. Numbers or Letters inside () are the previous day value. The risk level of the epidemic in each region is derived from the value of R and the dynamics of infections, ordering from A to F with increasing severity.

Rank	Country	R	Active Cases on March 28	Undiagnosed Cases (in k)	New Cases in Past 7 Days (in k)	Projected New Cases in Next 7 Days (in k)	Projected Ending Time	Projected Final Size (in k)	Risk Level
1	US	6.45++	102.2(83.8)	91.5	85.2	185–210	2020/11/5-2021/1/4	1,002-2,563	F
2	Spain	3.86++	57.2(52.2)	40.5	47.3	78–85	2020/11/8-2021/2/27	538-2,023	F
3	Italy	1.79++	66.4(62.6)	28.9	39.5	41–45	2020/9/21-2020/10/12	186-232	F
4	UK	6.42++	13.7(11.1)	13.2	10.6	31–34	NA	NA	E(D)
5	France	3.87++	25.3(22.5)	19.2	20.4	37–41	2020/12/28-2021/10/27	716-55,261	E
6	Iran	3.13++	21.2(18.8)	15.2	14.8	24–25	2021/5/31-2021/7/10	451-659	E
7	Germany	3.06++	41.8(37.3)	28.0	28.5	41–45	2020/10/16-2020/11/30	196-312	E
8	Canada	5.21++	4.5(3.8)	3.4	3.7	5–9	2020/8/10-2022/2/8	13.7-4,703	D(C)
9	Belgium	6.21++	8.4(6.6)	8.0	6.3	17–19	NA	NA	D
10	Austria	4.65++	7.4(6.3)	5.8	5.3	12–14	2020/10/20-2021/7/13	98-7,921	D
11	Holland	2.96++	5.6(7.0)	4.1	5.6	5–8	2020/8/12-2021/1/7	18-152	D
12	Norway	2.35++	3.8(3.3)	2.0	1.8	3.1–3.6	2021/2/8-2022/7/8	37-4,238	D
13	Sweden*	1.97++	2.9(2.7)	1.3	1.4	1.2–2.6	2020/7/22-2022/11/11	5-8,344	D

14	Denmark*	1.58++	2.0(1.8)	0.8	0.7	0.8–1.4	2020/7/17-NA	3-2,638	D
15	Switzerland*	1.61	10.4(11.6)	4.3	6.0	4.8–6.1	2020/8/13-2020/8/30	2-27	D
16	Korea	0.26--[19]	4.5(4.7)	0.6	0.07	0.6–0.7	2020/8/6-2020/9/6	11-12	D
17	Singapore	1.65++	2.0(1.9)	0.8	1.1	1.0–1.4	2020/8/5-2020/11/12	4-13	C
18	Thailand	2.22	1.1(1.0)	0.5	0.8	0.6–0.9	2020/7/12-2020/8/12	2-4	C
19	Malaysia	1.53	0.6(0.5)	0.2	0.3	0.2–0.5	2020/7/2-2021/8/19	1-43	C
20	Japan	1.28	1.1(1.1)	0.3	0.5	0.3–0.6	2020/7/6-2021/4/17	2-13	C

Note 1: 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. *Sweden, Denmark, and Norway began to narrow the scope of detection to critically ill patients and high-risk groups (doctors, elderly, etc.) in early March. The epidemic may be underestimated.

Note 2: The reason why the 95% predicted interval for the final cumulative confirmed cases in France, Canada, Austria, Denmark, Sweden, and Norway is very wide is that the R value has not fallen recently.

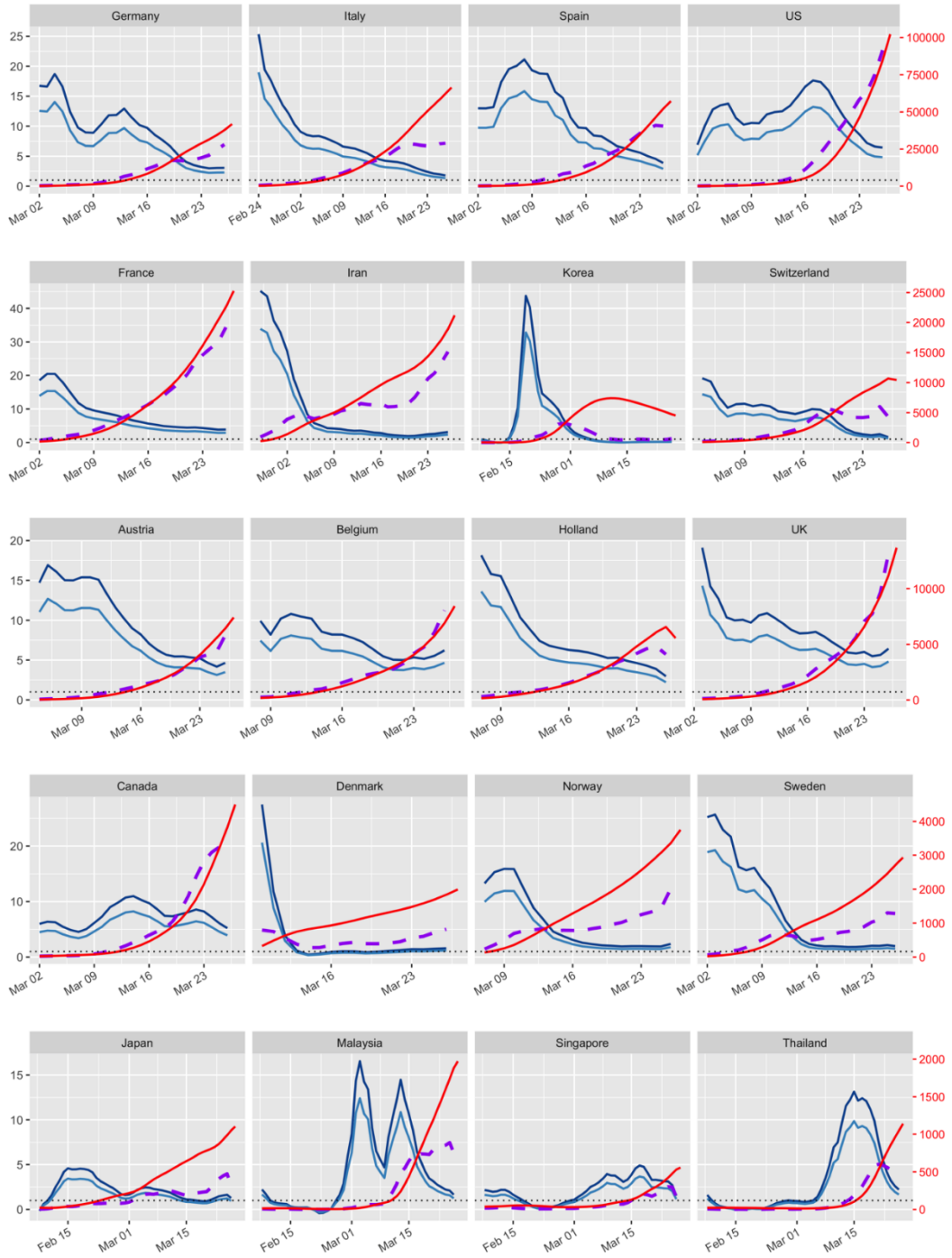

Figure 1. Time series plots of infected cases and estimated effective reproduction numbers R, the logarithm of infected cases (red) and the estimated logarithm of infected but undocumented cases (purple) up to March 28, 2020. Two Rs are given based on 10.5-day infectious duration (blue) and 14-day duration (navy blue). The critical threshold level R=1 is the horizontal dashed line.

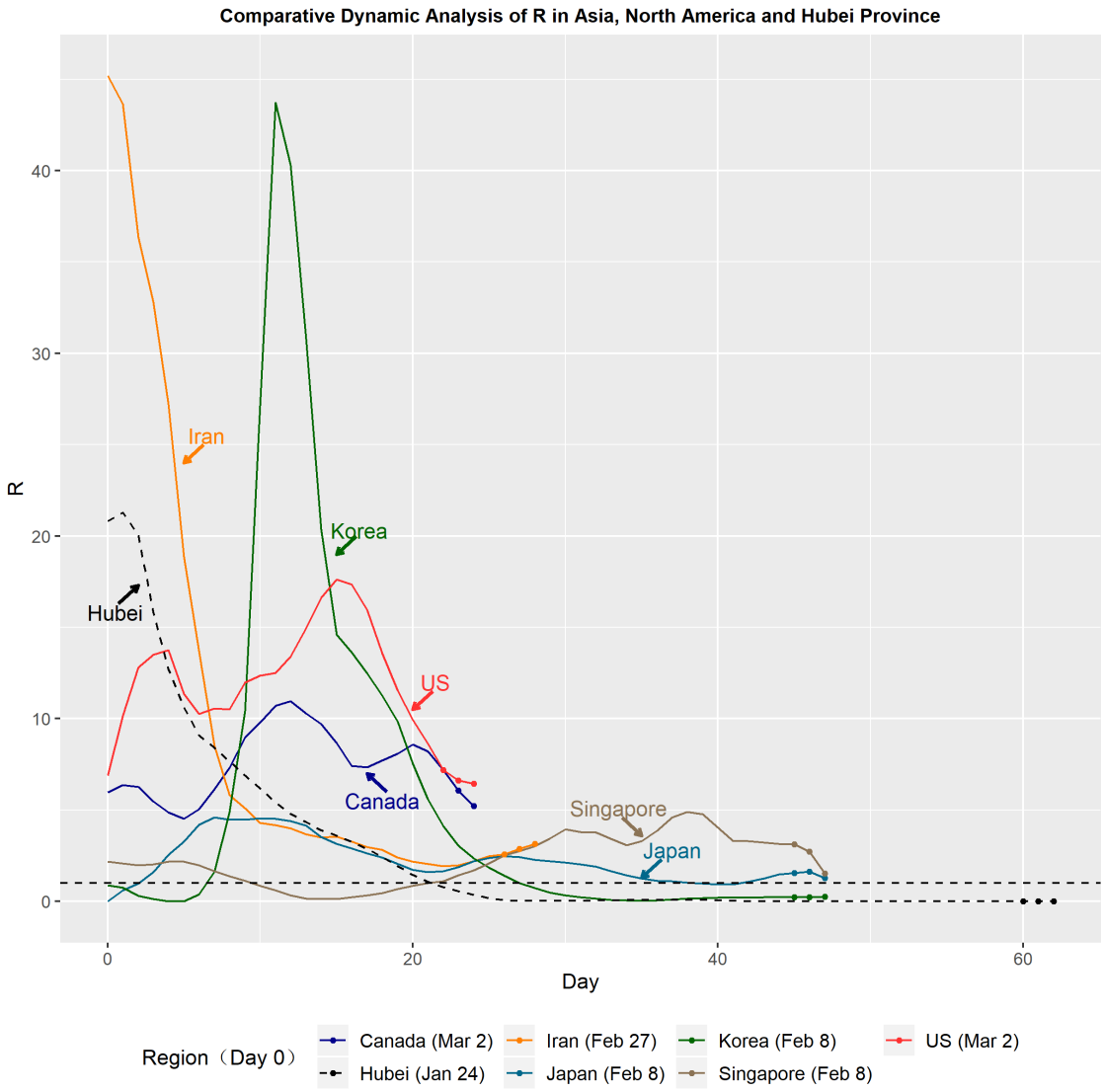

Figure 2.1. Effective Reproduction Number (R) in Canada, Iran, US, Korea, Japan, Singapore and Hubei Province in China up to March 28, 2020, based on a 14-day Infectious Duration. Day 0 is the fifth day since the outbreak as given in the legend. Points at the end of the line refer to the value of R of 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 comes to an end.

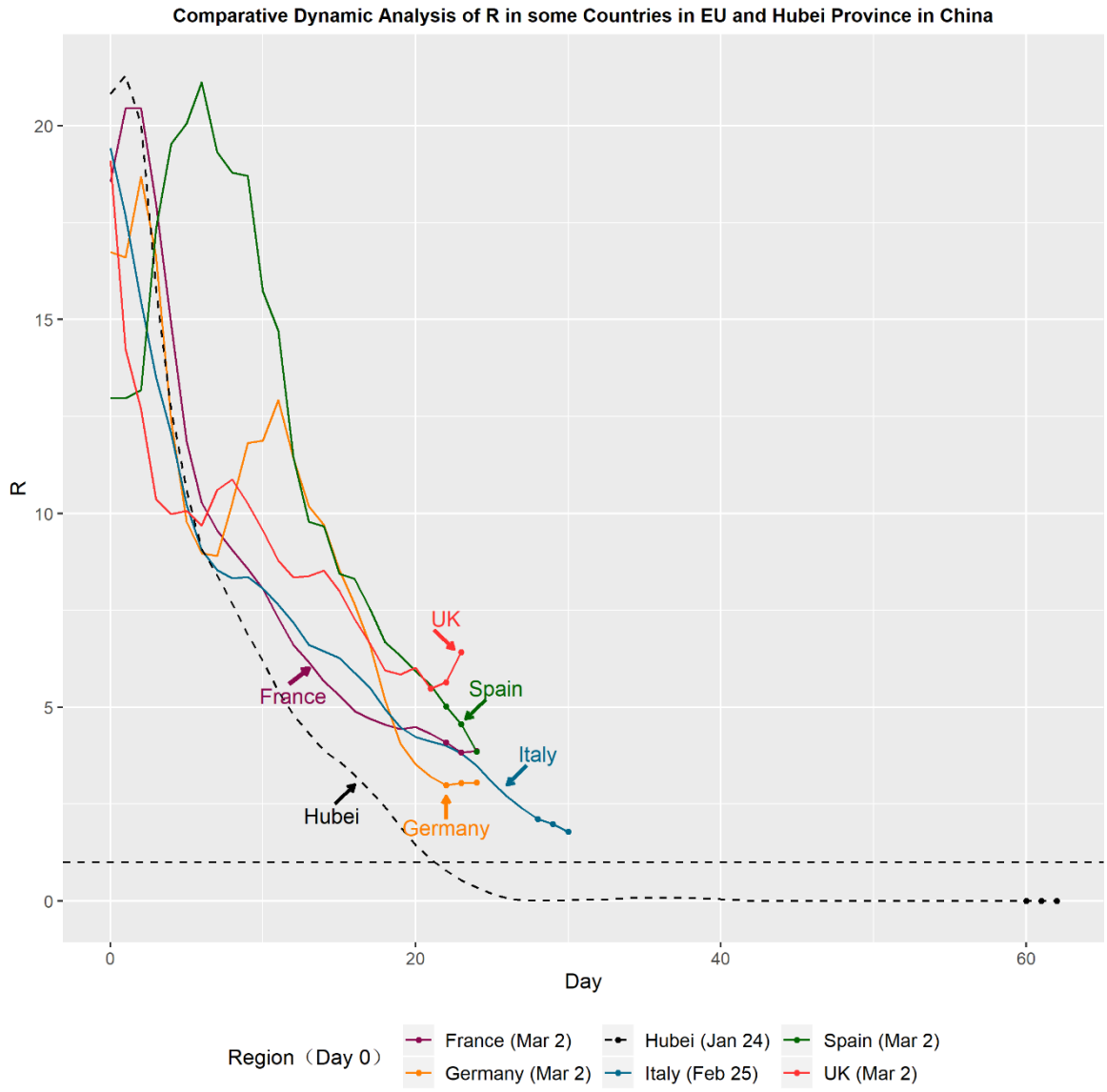

Figure 2.2. Effective Reproduction Number (R) in Europe and Hubei Province in China up to March 28, 2020, based on a 14-day Infectious Duration. Day 0 is the fifth day since the outbreak as given in the legend. Points at the end of the line refer to the value of R of the recent 3 days. The critical threshold R=1 is marked by the horizontal dashed line. Only when R is less than 1, the outbreak begins to decline and gradually comes to an end.