北京大学 PEKING UNIVERSITY **IOWA STATE UNIVERSITY**

Time: 11 p.m. (Beijing Time), April 23, 2020

Daily Brief on International Epidemic Situation of COVID-19

America and Europe Reaching Turning Point While Russia Still in Grim

Data: Based on the outbreak data up to 8 p.m. (Beijing Time), April 21, 2020

24 Countries concerned: (1) Asia: Iran, Japan, Singapore and India(newly added); (2) Europe: Italy, Spain, France, Germany, UK, Switzerland, Sweden, Belgium, the Neitherlands, Denmark, Norway, Turkey, Portugal, and Russia(newly added); (3) North America: US and Canada; South America: Brazil and Peru(newly added); (4)Africa: Egypt(newly added); (5)Oceania: Australia.

Abstract: This report covers epidemic situation in 24 countries over the world. Compared with previous report, four countries with its outbreak under control are removed: North Korea, Malaysia, Thailand and Austria, and four new countries are added: Russia, India, Egypt, and Peru. As of data collected up to 8 p.m. (Beijing Time), April 21, 2020, the total confirmed cases in these 24 countries add up to 2.07 million people, accounting for 84% of accumulated confirmed cases overseas(total cases of 2.471 million). United States reached the turning point on April 15; eleven countries of Italy, Spain, France, Germany, UK, Belgium, Portugal, the Netherlands, Denmark, Norway and Switzerland have subsequently reached the turning point. Russia, which is still in the exponential growth phase, may become the new epicenter of epidemic in Europe. The global epidemic situation is still grim, with total 157k deaths and 502k cures. 95% of the final number of total infected people in 24 countries predicts a lower bound of 36.165 million, and an upper bound of over 700 million. Based on current data, the epidemic situation in 24 countries will continue until the end of this year or even next year. The long duration of overseas epidemic will undoubtedly have a more severe long-term impact on China's economy and national security.

Method: Apply the vSEIR model developed by our team to calculate the effective reproduction number R for each country. See a medRxiv posting for an early version based on vSIR model and applications on China province's epidemic analysis: https://www.medrxiv.org/content/10.1101/2020.02.17.20024257v1

Special terms: 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) Plots of the cumulative cases and infection rate for each country(Figure 2). (iii) Time series plots of the 14-day R of international areas along with China (excluding Hubei Province) to gain information on the epidemic stages (Figure 3-1 and 3-2).

Key Findings: (i) America: The rate of epidemic transmission in the United States exhibits a downward trend in the last week, and the 14-day R value (hereafter referred to as the R value) has further decreased to 0.83. Canada 's R value is 1.26, Brazil 's R value is 1.34, and Peru's R value has fallen below 1 for the first time, at 0.97.

(ii) Europe: The European epidemic has eased comparing to pervious weeks. Italy, Spain, France, Germany, the United Kingdom, Belgium, Portugal, the Netherlands, Denmark, Norway, and Switzerland have R values less than 1 for more than 7 days continuously, and have all reached turning points recently. Sweden's R value fluctuates around 1. Although Russia's R value continues to decline, the number of infected people is still in an exponential growth stage, possibly becoming a new epidemic outbreak center. At present, the average value of R value in 14 countries is 0.71, decreasing from the average value of 0.81 in 14 countries 7 days ago, with 638.8k active cases. Currently, Russia has the highest infectivity R value of 1.7 (43.3k active cases), and Sweden's R value is 1.02 (12.6k active cases). Based on current data, we estimate that there are currently 259.2k potential cases in 14 European countries that have not yet been tested, accounting for 40.58% of the current active cases. It is expected that there will be 175.2k to 189.7k new cases in the next 7 days. The German epidemic is expected to

end in September 2020 (that is, the confirmed cases are cleared), the French epidemic will end in October, and the Spanish epidemic will continue until December.

(iii) Asia: The Japanese epidemic situation turned around, and the R value continues drop to 0.53. It is predicted that the epidemic will end in November 2020. The Iran's R value has been below 1 for 20 consecutive days, and the epidemic turning point was reached on April 7. The situation in Singapore is still in stalemate; the epidemic is at the early stage of local outbreak, exhibiting great uncertainty for future development. India's epidemic is also at the initial outbreak stage. The 14-day R value is 1.35 and the rate of decline is slow; its epidemic may continue until 2021 or even 2023.

Other Findings：

1. The 14-day R value in the United States (hereinafter referred to as the 14-day R value) is 0.83, which has been less than 1 for 11 consecutive days, confirming that it has reached the turning point. There are 672.1k active cases, with a daily new confirmed cases of more than 20k for 23 consecutive days. We estimate a total of 168.4k potential cases, and an increase of more than 170k cases in the next 7 days. The cumulative number of infections will exceed 900k. Based on the current infectious regeneration and removal rate in the United States, the epidemic is expected to end from February to March 2021 (one month later than the previous report). The final number of infected people will be between 1.38 million and 1.65 million. Risk rating is F. The R value of Canada is 1.26, which exhibits a increasing trend for the past 12 days. The development of the epidemic situation is not yet clear. More than 22k people have been tested positive, and there are another 8.9k potential cases. It is estimated that more than 10k new cases will be confirmed in the next 7 days, with a risk rating of D.

2. The epidemic situation in UK starts showing signs of easing. The R value of the 14-day period is 0.81, which has been less than 1 for 7 consecutive days. UK was confirmed to reach the turning point on April 20. There are 107.8k confirmed cases in the UK, with a mortality rate of about 13.3% and a cure rate of only 0.36%. The current number of potential cases is estimated at 50.6k. It is estimated that there will be 36k to 39k new cases in the next 7 days, which is equivalent to the number of newly confirmed cases (36k) in the past 7 days. After the UK's R value fell below 1 for the first time 7 days ago, the rate of decreasing slows down. If the range of forecast widens, its R value showed a slight rebound trend in the past 3 days, and the development of its epidemic situation is still uncertain. It is expected that the epidemic may continue until 2021, and the final cumulative number of infected people will reach 279.5k to 794.6k people, with the estimated interval is narrower than the previous time. The risk rating is maintained at the highest level of F.

3. Turkey's epidemic situation has improved. The 14-day R value is 0.83, which has been less than 1 for 6 consecutive days. They may reach the turning point in the near future. There are 75.4k active cases in Turkey, with an estimated of 41.8k potential cases. There have been 29.9k new cases in the past 7 days. It is expected that the number of new cases will decrease to about 30k in the next 7 days. It is estimated that the end of the epidemic will be from January to March 2021, and the total infected population will be between 183.1k to 278.7k, and the risk rating downgrades to E.

4. The R value of Italy is 0.4, which has been less than 1 for 24 consecutive days. It reached the turning point on April 1, and the epidemic situation is under controlled and enters the stationary period. In Italy, a total of 181.2k people have been tested positive and among 108.2k are active cases. The mortality rate has increased slightly from 13.0% to 13.3% in the past 7 days. The cure rate has steadily increased to 27%. The estimated number of potential cases is 27.7k, and it is expected that 15k new cases will confirm in the next 7 days. The Italy's R value has been declining slowly since April 7, and the range of estimated end of the epidemic is narrower than April 14. If the prevention and control is effective, the epidemic will end in early December 2020. If the prevention and control is not effective, the epidemic may continue until 2021. In March, a total of 211.1k to 271.8k cases of infections are expected, and the outbreak risk rating is maintained at F.

5. Spain's 14-day R value has been below 1 for 21 consecutive days. The turning point was confirmed on April 5th. It rebounded slightly from 0.5 to 0.9 in the past two weeks. It is expected to end the epidemic in December 2020. Total infection is expected to be about 240k, and the epidemic rating was maintained at F. A total of 200k cases were diagnosed, the cure rate rose to 40.4%, and the mortality rate remained at about 10%. There are 100k existing cases, and it is estimated that there are still about 40k potential cases. In the past 7 days, 31.6k new cases were confirmed, and it is expected that the number of newly confirmed cases will decrease to 20k in the next 7 days.

6. The epidemic situations in Germany and France were effectively controlled. The turning points were confirmed on April 8 and April 7, expecting to end the epidemic in mid-September 2020 and the end of October, respectively, both with a risk rating of D. Germany's current R value is 0.59, which has been less than 1 for

18 consecutive days. There are 43.7k existing cases and the mortality rate is only 3.2%, which remains at a low level. 18.4k new cases were confirmed in the past 7 days, and the number of new cases is expected to drop to below 10k in the next 7 days. It is expected that the epidemic will end in mid-September(two months in advance than previous report). By then, it is expected that the total number of infected cases will reach 160k, the final number of infections is predicted to be the same as the previous results. The R value in France has remained at zero for 4 consecutive days, with 55.2k active cases and a high mortality rate of 17.8%. There were 13.9k new cases in the past 7 days. The trend will gradually ease with expected 5k new cases in the next 7 days. It is expected that France will end the epidemic by the end of October 2020, while the toal infected people will reach 120k, which is similar to the previous report.

7. Iran's 14-day R value is less than 1 for 20 consecutive days, and the turning point was confirmed on April 1. There are 18.5k active cases, which is a decrease from a few days ago, with a total of 5.3k deaths. It is estimated that the cumulative number of infected people by the end of the outbreak is about 100k to 110k, with a risk rating of E.

8. Russia's 14-day R value is 1.7, and the epidemic situation is in a stage of rapid rise, with a risk rating of E. There are 43.3k active cases, and 28.8k confirmed cases have been added in the past 7 days. It is predicted that there will be about 40k new cases in the next 7 days, and the epidemic will reach the end in January to March, 2021.

9. The R value of India in the 14-day period is 1.35, and the epidemic is at the beginning of outbreak. Recently the R value has been declining slowly with a slow rate, showing the epidemic has not been effectively controlled. There are 14.7k existing cases, and it is predicted that 10k to 20k more will be added in the next 7 days. Because the R value is significantly greater than 1 and there is no obvious rapid downward trend, if the control is not strengthened, the epidemic may continue until 2021 or even 2023.

10. Japan's 14-day R value fell to 0.53, which was less than 1 for 7 consecutive days. The epidemic situation turned positive, with 9.8k active cases. It is expected that 2.2k to 2.6k new cases will be added in the next 7 days. We predict that the epidemic will end in November 2020. However, since the high test standards in Japan and the suspected patients are only isolated at home, the number of diagnoses may be underestimated. The risk rating up to April 21 is D.

11. The R value in Singapore is 2.01, fluctuating continuously these days. The number of infected people shows an initial outbreak, and the outbreak of domestic cases mainly originates from the infection group of the guest dormitory. The development of the epidemic situation is still unclear, with a risk rating of D. The epidemic may be delayed until 2021.

12. Australia's 14-day R value is 0.18, which has been below 1 for 24 consecutive days. The inflection point of the epidemic was confirmed on April 2. There are 4.3k active cases, a total of moe than 6.6k people have been diagnosed, and 0.2k potential cases. It is estimated that about 0.1k new cases will be added in the next 7 days. The epidemic is expected to end from the end of June to the beginning of July 2020, with a cumulative infection of 6.8k to 6.9k cases.

13. Brazil's 14-day R value is 1.34, which is a decrease from the previous 1.62, but it is still significantly greater than 1, the existing cases exceed 15k, the potential cases are about 24k, and the estimated number of confirmed cases in the next 7 days is about 10k. The epidemic risk rating is D, and the epidemic is expected to end from June to July 2020. Peru's R value dropped from 1.45 to 0.97, falling below 1 for the first time, with a risk rating of D. There are currently 8.9k people diagnosed and about 47.7k potential cases. It is expected that the epidemic will end from October to December 2020.

14. Egypt's 14-day R value is 1.18, and the risk rating is D. There are 2.3k extant cases, a total of 3.3k people have been diagnosed, and 900 potential cases. It is estimated that there will be 0.8k to 1.4k new cases in the next 7 days. The development of the epidemic is unclear. Egypt's detection standards are high, prevention and control are loose, and the number of diagnoses may be underestimated. The epidemic will continue for a long time without taking more powerful prevention and control measures.

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

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

Table 1. Effective Reproduction Number (R) on April 20, 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 April 20	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	Spain	0.9[21](0.75)	100.4	42.6	31.6	20.1 - 23.3	2020/12/5 - 2020/12/10	239.7 – 257.8	F
2	US	0.83[11](0.92)	672.1	168.4	205.4	174.9 - 184	2021/2/11 - 2021/3/16	1,381.6 – 1,648.8	F
3	Italy	0.4[24](0.62)	108.2	27.7	21.7	15 – 17.4	2020/12/6 - 2021/3/27	211.2 - 271.8	F
4	Turkey	0.83[6](1.11)	75.4	41.8	29.9	27.6 – 30.1	2021/1/13 - 2021/3/24	183.1 – 278.7	F
5	UK	0.81[7](1.05)	107.8	50.6	36.1	36 - 39	2021/1/10 - 2021/12/30	279.5 – 794.6	F
6	Russia	1.7(2.09)	43.3	26.4	28.8	41.7 – 49.9	2021/1/1 - 2021/3/6	173.3 - 576	E
7	India	1.35(1.49)	14.7	6.7	8.1	10.5 - 12.4	2021/1/11 - 2023/3/22	73.9 – 644,462	E
8	Iran	0.77[20](0.73)	18.5	9.1	9.9	7.2 - 7.5	2020/9/28 - 2020/11/4	104.7 – 111.5	E
9	Germany	0.59[18](0.42)	43.7	22.2	18.4	9.4 – 9.7	2020/9/9 - 2020/9/18	160.9 – 163.4	E
10	France	0.01[19](0.45)	55.2	13.9	16.5	5 – 5	2020/10/27 - 2020/10/31	120.8 – 120.9	E
11	Canada	1.26(1.19)	22.6	8.9	11.2	12.9 – 13.8	2022/3/17 - 2024/5/25	343 – 13,157.1	D
12	Brazil	1.34(1.62)	15.8	24.7	16.8	9.5 – 11.4	2020/6/28 - 2020/7/8	54.5 – 61.6	D
13	Egypt	1.18(1.3)	2.3	0.9	1.1	0.8 – 1.4	2020/9/18 - 2022/11/27	4.6 – 57,005.5	D

| 14	Sweden*	1.02(1)	12.6	5.6	3.8	2.5 – 3.7	2020/10/20 - 2022/1/10	18.7 – 77.5	D
15	Peru	0.97[1](1.45)	8.9	4.7	6.5	5.2 – 6.4	2020/10/14 - 2020/12/19	26.9 – 49.5	D
16	Denmark*	0.85[14](0.63)	2.7	0.9	1.2	0.6 - 0.9	2020/7/5 - 2020/10/10	8.5 – 11.2	D
17	Belgium	0.76[11](0.91)	26	12.2	9.8	5.4 – 6.7	2020/10/26 - 2020/11/17	51.3 – 63.4	D
18	Portugal	0.65[15](0.64)	19.5	4	3.9	3.7 – 4.1	2020/12/12 - 2021/5/20	34.1 – 59.3	D
19	Holland	0.65[11](0.83)	29.3	9.5	6.9	6.4 – 6.8	2020/12/27 - 2021/2/24	61.9 - 82	D
20	Norway*	0.41[23](0.35)	6.9	0.5	0.6	0.3 - 0.6	2020/10/22 - 2021/2/2	7.6 – 11.4	D
21	Switzerland	0.35[21](0.55)	7.8	1.3	2.4	0.9 – 1.4	2020/8/6 - 2020/10/18	28.9 – 32.7	D
22	Singapore	2.01(2.65)	5.8	5.6	4.1	6 – 8.8	2020/12/2 - 2021/11/6	24.6 – 4,725.5	D
23	Japan	0.53[7](1.06)	9.8	4.4	3.5	2.2 – 2.6	2020/11/6 - 2020/11/22	15 – 19.2	C
24	Australia	0.18[24](0.09)	2.3	0.2	0.3	0.1 - 0.1	2020/6/23 - 2020/7/11	6.8 – 6.9	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.

Note 2: 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.
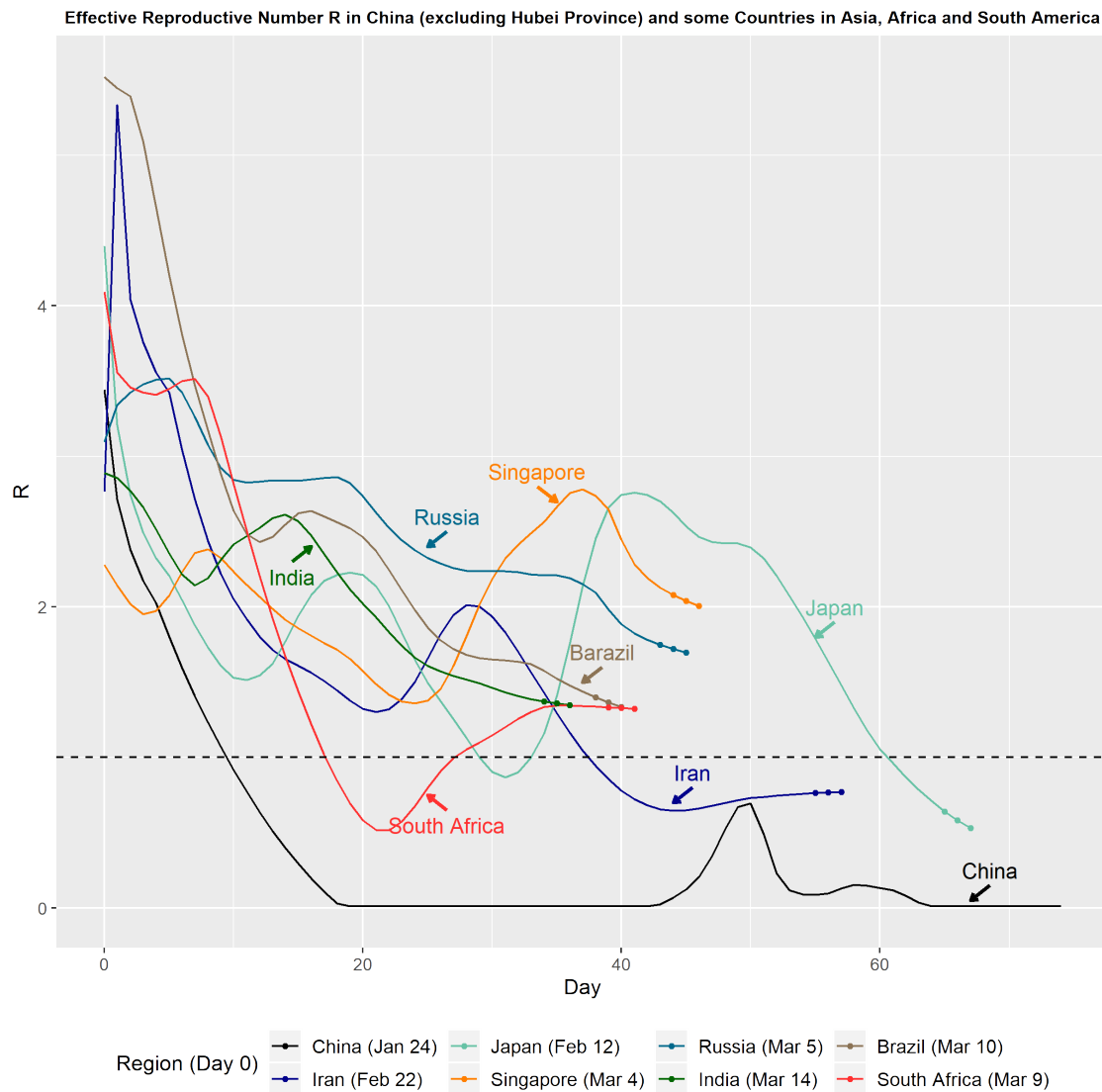
Note 3: The reason why the 95% predicted interval for the final cumulative confirmed cases in India, Egypt, Canada and Singapore is very wide is that the R value has not fallen recently.
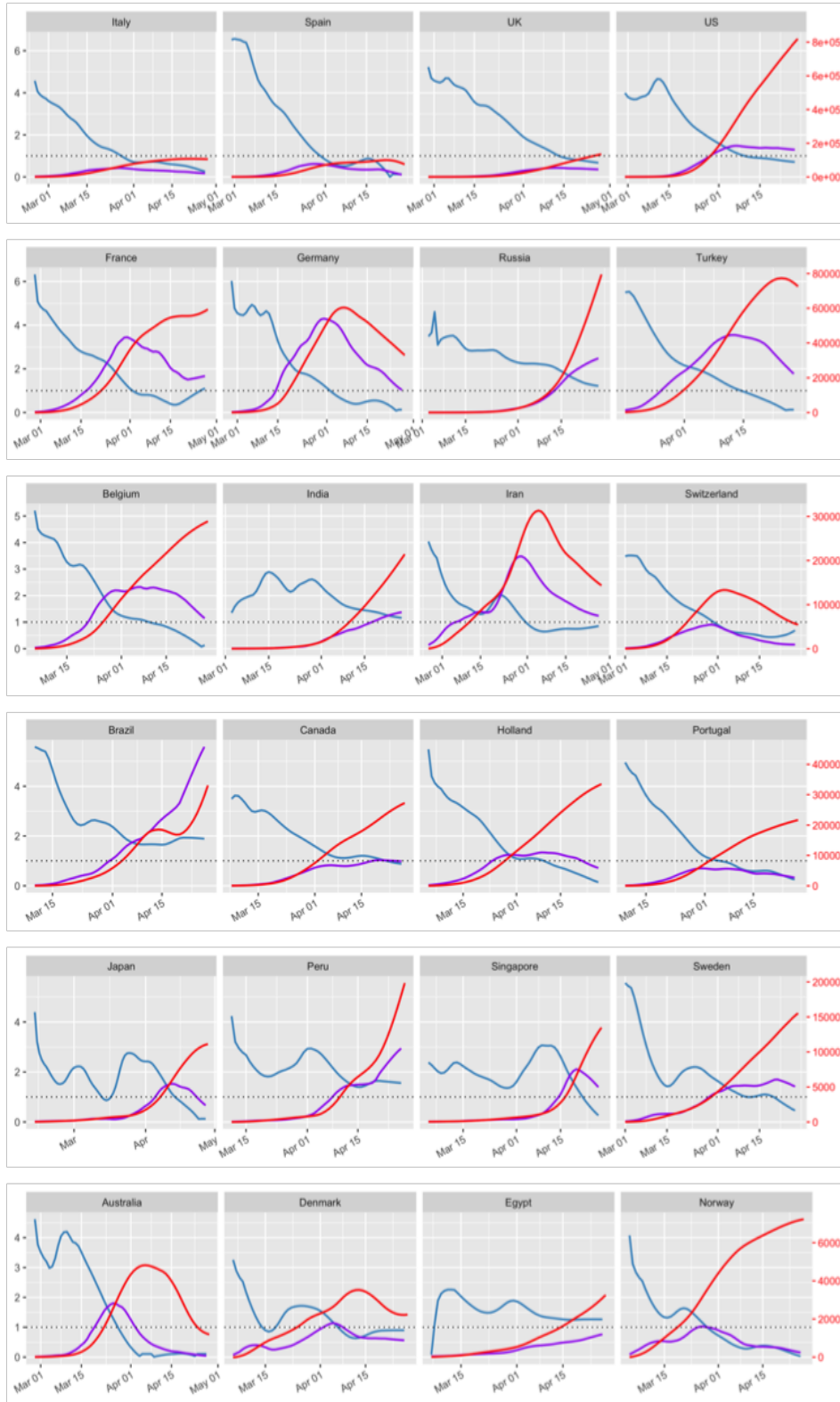
Figure 1. Time series plots of infected cases and estimated effective reproduction numbers R, the logarithm of infected cases (red, up to April 21) and the estimated logarithm of infected but undocumented cases (purple) up to April 20, 2020. Two Rs are given based on 10.5-day infectious duration (blue) and 14-day duration (navy blue). The critical threshold level R=1 is the horizontal dashed line.
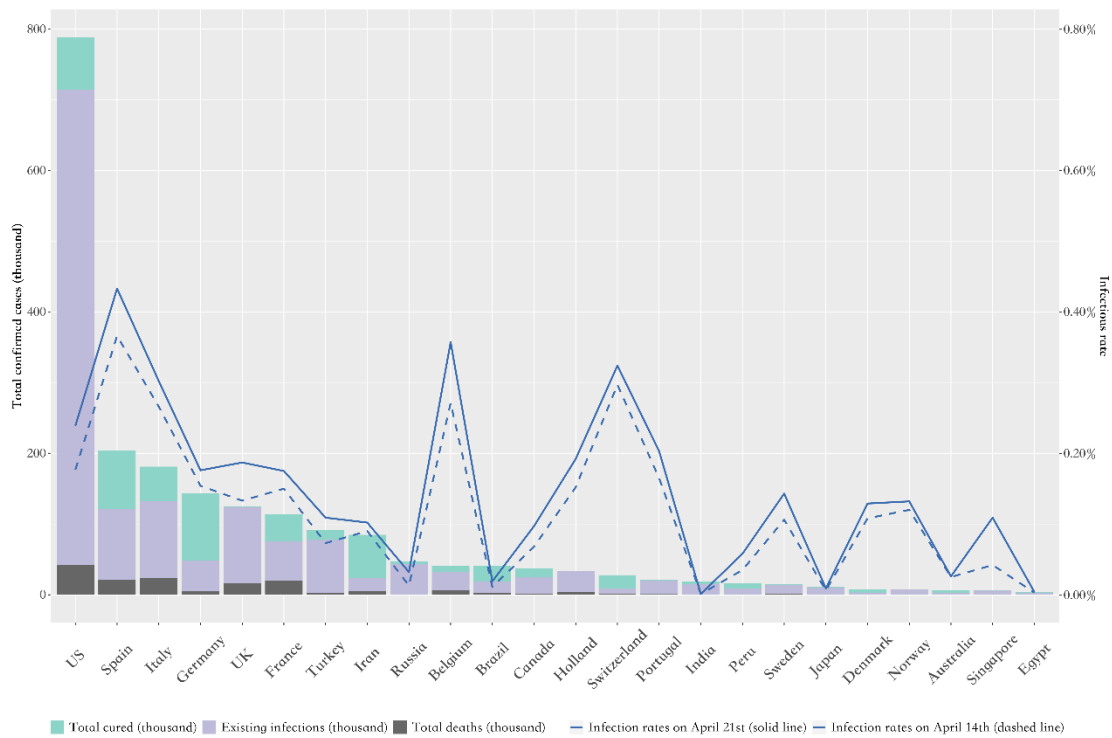
Figure 2. The cumulative number of cases and population infection rates up to April 21, 2020 in each country. Green: cumulative number of people cured; purple: number of existing infections; gray: cumulative number of deaths; solid blue line: population infection rate; blue dotted line: population infection rate 7 days ago.

Effective Reproductive Number R in China (excluding Hubei Province) and some Countries in Asia, Africa and South America

Figure 3.1. Effective Reproduction Number (R) in China (excluding Hubei Province) and Asia, Africa and South America up to April 21, 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.

Effective Reproductive Number R in China (excluding Hubei Province), US and some European Countries
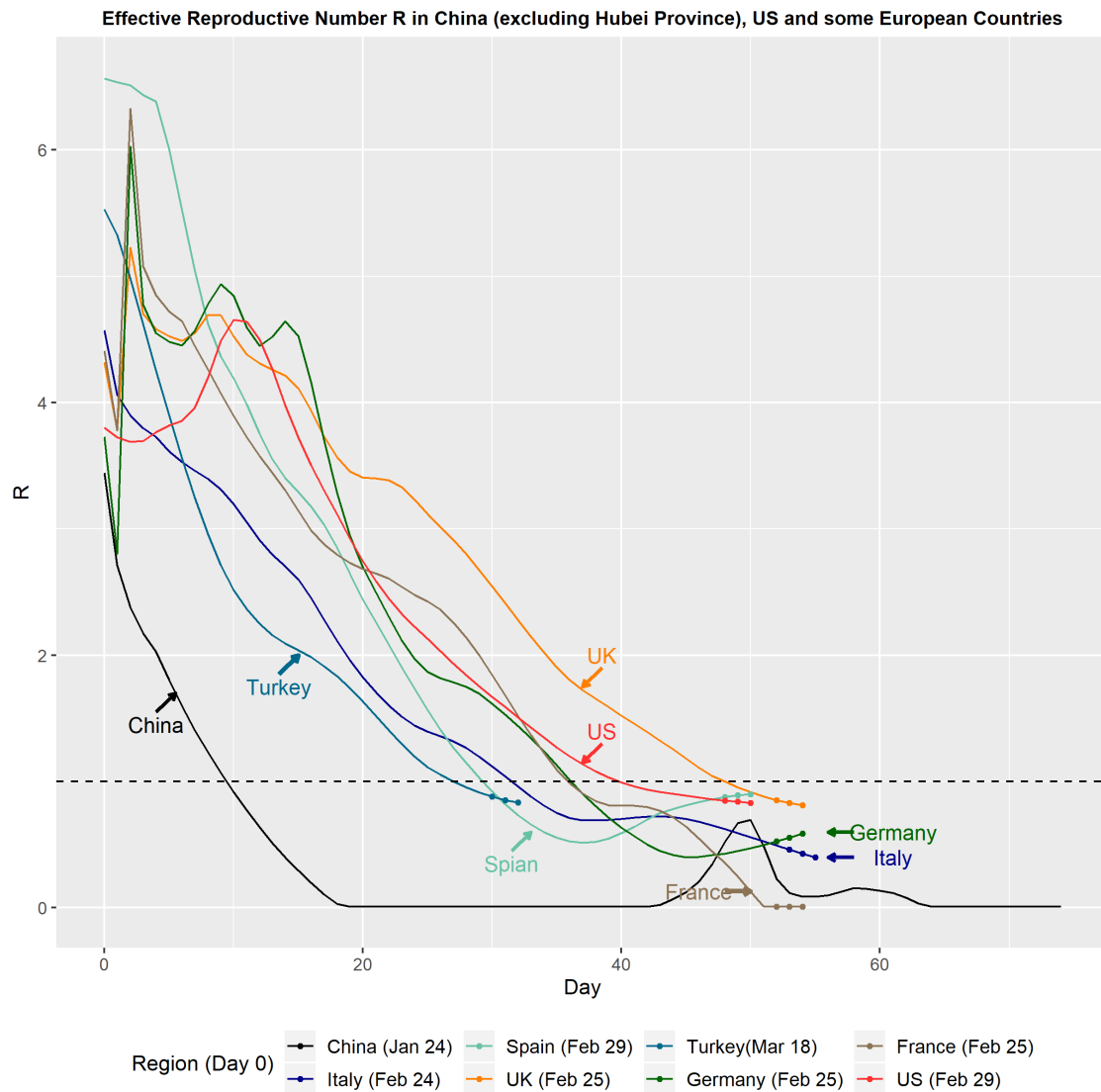
Figure 3.2. Effective Reproduction Number (R) in US, Europe and China (excluding Hubei Province) up to April 20, 2020, based on a 14-day Infectious Duration. Day 0 is the fifth day since the outbreak as given in the legend. Points at the end of the line refer to the value of R of the recent 3 days. The 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.