Daily report 15-07-2020

Analysis and prediction of COVID-19 for EU-EFTA-UK and other countries

Situation report 102
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With the financial support of:
Foreword

The present report aims to provide a comprehensive picture of the pandemic situation of COVID-19 in the EU countries, and to be able to foresee the situation in the next coming days.

We employ an empirical model, verified with the evolution of the number of confirmed cases in previous countries where the epidemic is close to conclude, including all provinces of China. The model does not pretend to interpret the causes of the evolution of the cases but to permit the evaluation of the quality of control measures made in each state and a short-term prediction of trends. Note, however, that the effects of the measures’ control that start on a given day are not observed until approximately 7-10 days later.

The model and predictions are based on two parameters that are daily fitted to available data:

- $a$: the velocity at which spreading specific rate slows down; the higher the value, the better the control.
- $K$: the final number of expected cumulated cases, which cannot be evaluated at the initial stages because growth is still exponential.

We show an individual report with 8 graphs and a table with the short-term predictions for different countries and regions. We are adjusting the model to countries and regions with at least 4 days with more than 100 confirmed cases and a current load over 200 cases. The predicted period of a country depends on the number of datapoints over this 100 cases threshold, and is of 5 days for those that have reported more than 100 cumulated cases for 10 consecutive days or more. For short-term predictions, we assign higher weight to last 3 points in the fittings, so that changes are rapidly captured by the model. The whole methodology employed in the inform is explained in the last pages of this document.

In addition to the individual reports, the reader will find an initial dashboard with a brief analysis of the situation in EU-EFTA-UK countries, some summary figures and tables as well as long-term predictions for some of them, when possible. These long-term predictions are evaluated without different weights to data-points. We also discuss a specific issue every day.

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Disclaimer: These reports have been written by declared authors, who fully assume their content. They are submitted daily to the European Commission, but this body does not necessarily share their analyses, discussions and conclusions.
(0) Executive summary – Dashboard
Situation and highlights

Romania is clearly experiencing a second wave. If the peak of the first wave reached a level of 400 daily new cases, they are now at the level of 600 without signs of control. Nevertheless, its current relative incidence is at degree 5 in the Biocom-Cov2 scale, which is lower than in some countries that are already in the tail. Bulgaria and Croatia are also in a similar situation, but with lower absolute number of cases.

Other countries are showing new local outbreaks that are perceived at the country level but that are lower than first wave. The relative importance of these outbreaks depend on the regions’ capacity for controlling them. If we look at their Biocom-Cov2 degree, we see that new outbreaks have pushed Luxembourg up to degree 7, Portugal to 6, Switzerland, Czech Republic and Austria to 3. Sweden remains at an uncertain situation, with a Biocom-Cov2 degree equal to 6 but a $\rho_7$ below 1 for the last week.

Last weeks, there are some countries that show many gaps on data (Spain, France, Denmark and Sweden, among others), most of these gaps corresponding to weekends. These gaps make the automatic analyses very difficult with current methodology, if they persist the whole methodology should be revised.
Situation and trends per country

Table of current situations in EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) from worst (red) situations according to each of the variables. Last column (EPGEST) is assessed with estimated real 14-day attack rate (see report from 22/04 for details). EPGREP is calculated with data reported by countries. EPGREP and EPGEST cannot be compared between them because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively. Data from 2nd July.

<table>
<thead>
<tr>
<th>Country</th>
<th>Cumulative cases</th>
<th>Attack rate /10^6 inh.</th>
<th>Cumulative deaths /10^6 inh.</th>
<th>Mortality /10^6 inh.</th>
<th>Active cases (last 14 days)</th>
<th>14-day attack rate /10^6 inh.</th>
<th>Estimated active cases (last 14 days)</th>
<th>Estimated 14-day attack rate /10^6 inh.</th>
<th>p_7</th>
<th>Biocom-Cov degree</th>
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Data from 2nd July.

Disclaimer: estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1 % (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher)

1) p_7 is the average of 7 consecutive p_6 but can still fluctuate.

2,3) EPG stands for Effective Growth Potential. EPGREP is the product of attack-rate of last 14 days per 10^5 inhabitants by p_7 (empiric reproduction number). EPGEST is the product of estimated real attack-rate of last 14 days per 10^5 inhabitants and p_7. Biocom-Cov degree is an epidemiological situation scale based on the level of last week’s mean daily new cases (https://upcommons.upc.edu/handle/2117/189661, https://upcommons.upc.edu/handle/2117/189808).
Analysis: Different measurements of epidemics speed propagation. On the meaning of a basic reproductive number in a non-disperse epidemics.

We find that one of the main drawbacks in characterizing the epidemic outbreaks is the importance given to the basic reproductive number as if it were a characteristic value of each type of disease. It is not correct to talk about $R_0$ as being something inherently characteristic of the disease and the way it is transmitted. Many circumstances modulate the number of people who will become infected when the spread begins. The basic reproductive number ($R_0$) depends on the number of susceptible people, as Kermack and McKendrick deduced, but it also depends on how they behave, population density and mobility, among others. The Covid-19 epidemic has been a good example of $R_0$ being too ambiguous. $R_0$ may only be of interest in recurrent epidemics such as influenza, where the number of susceptible people and their behavior can be considered similar from one year to the next. Trying to overcome this problem, we propose here that another approach to measure velocity of propagation would be clearer.

Epidemiology and microbiology are two of the disciplines related to biological systems where mathematics has been used normally for many decades. A common challenge for both is to measure the growth rate of the system and the causes that determine it.

- In microbiology we have two extremes. In industrial production, we need the growth rate to be as high as possible, whereas in food security we need the speed to be as low as possible. Today, the physical and chemical factors that determine the growth rate of crops are very well known.
- In epidemiology we need to be able to objectively measure the rate of disease spread, as well as to know the factors that determine the magnitude of that rate.

Most microbiological systems of industrial or biomedical interest are quite complex, although they are often characterized by a known or limited composition. Variables like temperature and pH, among others, are very well controlled. Contrarily, biological systems that suffer from epidemics and pests tend to be much more complex and difficult to define and control. For example, microbial culture systems are often performed in a bioreactor or in containers where space is a not too important variable, while the spread in space is one of the most important factors in epidemiology. Nevertheless, microbiology and epidemiology are two areas of knowledge that are conceptually close from the point of view of mathematics, which is why it can be very useful to take advantage of solutions from one of the fields to solve problems in the other discipline.

Let us recall here the specific growth rate in microbiology:

$$\mu = \frac{1}{m} \frac{dm}{dt}$$

Here, $m$ is the biomass (or any other quantitative variable). $\frac{dm}{dt}$ is the velocity at which biomass is produced. Finally, its division by the biomass results on the velocity of biomass production per each unit of mass, i.e., the specific growth rate. We can try now to translate this strategy of using the specific framework in epidemiology. We can mimic the former definition and test if this specific rate could be useful to describe the pandemic. Following this epidemiological strategy, we can define the specific propagation rate as:

$$\mu = \frac{1}{N} \frac{dN}{dt}$$

Given that in epidemics the basic unit of time is a day, we must use finite differences and not derivatives. Therefore, the proper definition for the specific velocity should read

$$\mu = \frac{1}{N} \frac{\Delta N}{\Delta t}$$
where \( N \) are the active cases (i.e., those cases with the ability to transmit the disease). In this epidemic, active cases can be represented by the variable \( A_{14} \), i.e., the cumulative incidence of last 14 days).

If \( \mu \) is small, the number of active cases will decrease over time. If it is large it will increase. We can deduce for which specific rate threshold value the number of active cases remains constant in the case of Covid-19. Consider now the limit of epidemic control where the daily number of new cases is always the same, \( \Delta N \), in which case the number of active cases is \( N = 14 \Delta N \).

Therefore:

\[
\mu = \frac{1}{N} \frac{\Delta N}{\Delta t} = \frac{1}{14} \frac{\Delta N}{\Delta t} = \frac{1}{14} \frac{1}{\Delta t} = \frac{1}{14} \cdot 1 \text{ day}^{-1} = 0.07143 \text{ day}^{-1}
\]

In other words, now the control limit is not 1, like in \( R_0 \) or in \( R_t \), but roughly 0.07.

In epidemiology, the reproduction number is usually used to assess the speed of propagation, the basic reproduction number or the specific reproduction number is used. These are concepts that emerged with the first mathematical models, such as the SIR of Kermack and McKendrick of the early twentieth century.

We will see that the reproduction number is indeed a good tool to measure the speed of spread of the disease and instead is not a good tool to talk about the number of people who infect each infectious person.

We use the empirical reproductive rate \( (\rho_t) \) by quoting the average of three three-day new cases divided by the three-day average of new cases five days earlier. To perform the following calculations, we performed a 7-day run average on the list of new cases, in order to decrease oscillations and the weekend effect. In the following figures we represent the two magnitudes for the evolution we have had in Iran.
We see how the behavior of $\mu$ and $\rho_2$ are very similar, we see especially in the third plot (bottom) where we draw the two parameters normalized to 1. We can say, in fact as everyone knows, that the reproductive number is excellent indicator of the speed of spread of the epidemic.

The other interpretation of the reproductive number, on the other hand, is not at all appropriate and leads to many errors. Mathematically, the number can be interpreted as the average number of new cases caused by each infectious person. However, this is problematic. The first is to think that the reproductive number is indicative of how the infection is spreading, as if each person is more or less infecting the value found. In the case of Covid-19, and clearly in many other epidemics, we have people and circumstances who transmit with very high values and people who do so with very low values. In this case, the distribution and interpretation are much more interesting than the average value.
### Situation and trends in other countries

Table of current situation in a sample of non-EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables. $\text{EPG}_{\text{REP}}$ and $\text{EPG}_{\text{EST}}$ cannot be compared between them because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively. Data from 2nd July.

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<td>Attack rate /10^5 inh.</td>
<td>Cumulative deaths</td>
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</table>

Disclaimer: estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1% (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher).

(1) $\rho_T$ is the average of 7 consecutive $\rho$, but can still fluctuate. (2,3) EPG stands for Effective Growth Potential. $\text{EPG}_{\text{REP}}$ is the product of attack-rate of last 14 days per 10^5 inhabitants by $\rho_T$ (empiric reproduction number). $\text{EPG}_{\text{EST}}$ is the product of estimated real attack-rate of last 14 days per 10^5 inhabitants and $\rho_T$. Biocom-Cov degree is an epidemiological situation scale based on the level of last week’s mean daily new cases (https://upcommons.upc.edu/handle/2117/189661, https://upcommons.upc.edu/handle/2117/189808).
Time indicators by country

These tables summarize a few time indicators for each country: time since 50 cases were reported, time interval between an attack rate of $1/10^5$ inhabitants and an attack rate of $10/10^5$ inhabitants, and time interval between attack rates of 10 to 100 per $10^5$ inhabitants (only for countries that have overtaken this threshold). Data from 2nd July.

EU+EFTA+UK countries

<table>
<thead>
<tr>
<th>Countries</th>
<th>Days since the first 100 cases</th>
<th>Time interval between 1 and 10 cases / $10^5$ inh. (days)</th>
<th>Time interval between 10 and 100 cases / $10^5$ inh. (days)</th>
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## Other countries

<table>
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<tr>
<th>Countries</th>
<th>Days since the first 100 cases</th>
<th>Time interval between 1 and 10 cases / 10^5 inh. (days)</th>
<th>Time interval between 10 and 100 cases / 10^5 inh. (days)</th>
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<td>36</td>
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<tr>
<td>Belarus</td>
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<td>18</td>
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</tbody>
</table>
Long-term predictions

Evaluated with the **whole historical series.** Up-left: Predictions of maximum incidences per country at the end of the first wave (total final expected attack rate per $10^5$ inh.). Up-right: Predictions of maximum absolute number of cases per country at the end of the first wave ($K$, in log scale). Blue lines indicate current situation. Bottom-left: Time in which peak in new cases was achieved / will be achieved. Bottom-right: Time at which $90\%$ of $K$ was achieved / will be achieved. Blue dotted line indicates current date.

Final expected value for EU+EFTA+UK as a whole is not shown any more, since we are in the tail (see Analysis section in Report #87, [https://upcommons.upc.edu/handle/2117/190497](https://upcommons.upc.edu/handle/2117/190497)).
Situation and trends in Italian and Spanish regions

Italy

Data from 15th July

<table>
<thead>
<tr>
<th>Country</th>
<th>Cumulative cases</th>
<th>Attack rate /10^5 inh.</th>
<th>Cumulative deaths</th>
<th>Mortality /10^5 inh.</th>
<th>Active cases (last 14 days)</th>
<th>14-day attack rate /10^5 inh.</th>
<th>Estimated active cases (last 14 days)</th>
<th>Estimated 14-day attack rate /10^5 inh.</th>
<th>ρ7(1)</th>
<th>EPGREP(2)</th>
<th>EPGEST(2)</th>
<th>Biocom-Cov degree</th>
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<tbody>
<tr>
<td>Lombardia</td>
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<td>15,765</td>
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<td>110</td>
<td>11</td>
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</table>

Disclaimer: estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1 % (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher).

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Spain

Data from 6th July. Symptoms onset date.

<table>
<thead>
<tr>
<th>Autonomous regions</th>
<th>Cumulative cases</th>
<th>Attack rate /10^5 inh.</th>
<th>Active cases (last 14 days)</th>
<th>14-day attack rate /10^5 inh.</th>
<th>ρ7(1)</th>
<th>EPGREP(2)</th>
<th>EPGEST(2)</th>
<th>Biocom-Cov degree</th>
</tr>
</thead>
<tbody>
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<td>Madrid</td>
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<td>171.7</td>
<td>69</td>
<td>4.6</td>
<td>1.77</td>
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<td>Canarias</td>
<td>2,535</td>
<td>114.9</td>
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<td>1.6</td>
<td>1.45</td>
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<td>238.9</td>
<td>7</td>
<td>0.7</td>
<td>2.24</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Baleares</td>
<td>2,395</td>
<td>203.6</td>
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<td>4.1</td>
<td>0.98</td>
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<td>2.4</td>
<td>1.31</td>
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Long-term predictions are not shown any more, since all Italian and Spanish regions are already in the tail (see Analysis section in Report #87, https://upcommons.upc.edu/handle/2117/190497).
Legend: Countries’ reports details

- Reported cumulative cases (blue) and deaths (brown), together with predictions (red).
- Incident observed cases and predictions.
- Evolution of empiric reproductive number $\rho$.
- Risk diagram.
- Estimated and reported cases.
- Incident observed cases in a logarithmic scale, with Biocom-Cov degree.
- Case fatality rate.
- Risk diagram of last 15 days.
(1) Analysis and prediction of COVID-19 for EU+EFTA+UK

Spain 13-07-2020. Pop: 47.0M. Cumulative incidence: 544/10^5

[Graphs showing cumulative confirmed cases, confirmed cases per 10^6 inhabitants, and incident observed cases with time in days.]

BIOCOM-Cov2 Degree = 3

Actual $p_f = 1.6$

[Graphs showing case fatality rate with time in days.]
Italy 14-07-2020. Pop: 60.5M. Cumulative incidence: 402/10^5
Germany 14-07-2020. Pop: 83.8M. Cumulative incidence: 238/10^5

- [Graph showing cumulative confirmed cases and deaths]
- [Graph showing number of cases per 10^5 inhabitants]
- [Graph showing incident observed cases and predictions]
- [Graph showing incident observed cases per 10^5 inh.]
- [Graph showing actual r_f = 0.9]
- [Graph showing case fatality rate]
- [Risk diagram]
- [Risk diagram (last 15 days)]

Actual $r_f = 1.3$

Risk diagram

Risk diagram (last 15 days)

**Graphs showing cumulative confirmed cases, confirmed cases, estimated cases, and incident observed cases.**

**Actual 𝜌_f = 0.8**

**Risk diagram and risk diagram (last 15 days).**

![Graphs showing cumulative confirmed cases, confirmed deaths, predictions, and incident observed cases over time.](image)

**Actual ρ₀ = 1.1**

![Graph showing actual ρ₀ over time.](image)

**BIOCOM-Cov2 Degree = 6**

![Graph showing incident observed cases per 10^5 inh.](image)

**Risk diagram**

![Risk diagram showing active cases per 10^5 inh. over time.](image)

**Risk diagram (last 15 days)**

![Risk diagram showing active cases per 10^5 inh. for the last 15 days.](image)
Poland 14-07-2020. Pop: 37.8M. Cumulative incidence: 102/10^5
Denmark  14-07-2020. Pop: 5.8M. Cumulative incidence: 225/10^5

Cumulative confirmed cases

Cumulative confirmed deaths

Number of cases

Cases per 10^5 inhabitants

Incident observed cases

Incident observed cases per 10^5 inh.

Incident observed cases per 10^5 inh.

Actual $p_f = 1.6$

Case Fatality rate (%)

Risk diagram

Risk diagram (last 15 days)
Finland 14-07-2020. Pop: 5.5M. Cumulative incidence: 132/10^5
Luxembourg 14-07-2020. Pop: 0.6M. Cumulative incidence: 792/10^5

Actual $p_f = 1.3$

Risk diagram

Risk diagram (last 15 days)

Cumulative confirmed cases

Cumulative confirmed deaths

Number of cases

Cases per 10^5 inhabitants

Incident observed cases

Incident cases per 10^5 inh.

Actual \( \rho_Y = 1.0 \)

Case fatality rate (%)

Risk diagram

Risk diagram (last 15 days)

Cumulative confirmed cases

Incident observed cases

Actual $p_2 = 1.5$

BIOCMM-Cov2 Degree = 2

Risk diagram

Risk diagram (last 15 days)

[Graphs and diagrams showing cumulative confirmed cases, deaths, and predictions, and incident observed cases, incident cases per 10^5 inh., and case fatality rate (%). Each graph has time (days) on the x-axis and cumulative or incident cases on the y-axis.]

Actual \( \rho_2 = 2.9 \)

Risk diagram and Risk diagram (last 15 days)
Iceland 14-07-2020. Pop: 0.3M. Cumulative incidence: 558/10^5

Actual $\rho_1 = 1.0$

Risk diagram

Risk diagram (last 15 days)
Slovenia 14-07-2020. Pop: 2.1M. Cumulative incidence: 89/10^5

**Cumulative confirmed cases**

- Cases
- Deaths
- Predictions

**Cumulative confirmed deaths**

**Number of cases**

**Cases per 10^5 inhabitants**

**Incident observed cases**

- Confirmed
- Prediction

**Incident observed cases per 10^5 inh.**

**Incident observed cases per 10^5 inh.**

**Actual p_f = 0.9**

**Case Fatality rate (%)**

**Risk diagram**

**Risk diagram (last 15 days)**
Cyprus 14-07-2020. Pop: 1.2M. Cumulative incidence: 85/10^5

- **Confirmed cases**
- **Estimated cases**

**BIOCOM-Cov2 Degree = 2**

**Actual $p_Y = 2.4$**

**Risk diagram**

**Risk diagram (last 15 days)**
Malta  14-07-2020. Pop: 0.4M. Cumulative incidence: 153/10^5

- Cumulative confirmed cases
- Number of cases
- Incident observed cases
- Incident cases per 10^5 inh.
- Actual \( \rho_f = NA \)
- Case fatality rate (%)
- Risk diagram
- Risk diagram (last 15 days)
(2) Analysis and prediction of COVID-19 for other countries

USA 14-07-2020. Pop: 331.0M. Cumulative incidence: 1037/10^5
Brazil 14-07-2020. Pop: 212.6M. Cumulative incidence: 906/10^4

- Cases
- Deaths
- Predictions

Cumulative confirmed cases vs Time (days)

Cumulative confirmed deaths vs Time (days)

Number of cases vs Time (day)

Cases per 10^4 inhabitants vs Time (day)

Incident observed cases vs Time (day)

Incident cases per 10^3 inh. vs Time (day)

BIOCOM-Cov2 Degree = 9

Incident observed cases per 10^3 inh. vs Time (day)

Actual 𝑅邑 = 1.0

Case fatality rate (%) vs Time (day)

Risk diagram

Risk diagram (last 15 days)
Chile 14-07-2020. Pop: 19.1M. Cumulative incidence: 1671/10^5

![Graphs showing cumulative confirmed cases, confirmed cases, and incident observed cases. Actual p_f = 0.9. BIOMOC-Cov2 Degree = 8. Risk diagrams for the last 15 days.](image)

[Graphs showing cumulative cases and deaths, as well as incidence and observed cases over time.]

Actual $\rho_f = 1.0$

[Barchart and line graph showing actual and predicted cases per 10^3 inh.]

Case fatality rate (%)

[Graph showing case fatality rate over time.]
Iran 14-07-2020. Pop: 84.0M. Cumulative incidence: 312/10^5
Saudi Arabia 14-07-2020. Pop: 34.8M. Cumulative incidence: 683/10⁵
Turkey 14-07-2020. Pop: 84.3M. Cumulative incidence: 255/10^5

---

**Incident observed cases**

Actual \(\rho_I = 0.9\)

---

**Risk diagram**

July 14  
March 29

---

**Risk diagram (last 15 days)**

July 14  
June 29
Canada 14-07-2020. Pop: 37.7M. Cumulative incidence: 287/10^5

Cumulative confirmed cases

Cumulative confirmed deaths

Number of cases

Cases per 10^5 inhabitants

Incident observed cases

Incident cases per 10^5 inh.

Incident observed cases per 10^5 inh.

Case Fatality rate (%)

Risk diagram

Active cases per 10^5 inh. (last 14 days)

Risk diagram (last 15 days)

Active cases per 10^5 inh. (last 14 days)
Qatar 14-07-2020. Pop: 2.9M. Cumulative incidence: 3628/10^5

Cumulative confirmed cases vs. Time (days)

Cumulative confirmed deaths vs. Time (days)

Incident observed cases vs. Time (day)

BIOCOM-Cov2 Degree = 9

Actual $p_f = 0.8$

In incident cases per 10^3 inh.

Incident observed cases per 10^3 inh.

Case fatality rate (%) vs. Time (day)

Risk diagram

Risk diagram (last 15 days)
Argentina  14-07-2020. Pop: 45.2M. Cumulative incidence: 228/10^5

---

**Cumulative confirmed cases**

- Cases
- Deaths
- Predictions

---

**Cumulative confirmed deaths**

- Confirmed cases
- Estimated cases

---

**Incident observed cases**

- Confirmed
- Predicted

---

**Actual \( \rho \) = 1.6

---

**Active cases per 10^5 inh. last 14 days**

- June 29
- July 14
- May 21

---

**Risk diagram (last 15 days)**

- June 29
- July 14

- For cumulative cases and deaths over time, blue and red lines indicate confirmed cases and predictions, respectively.
- For cumulative confirmed deaths, a green line shows the estimated cases.
- Incident observed cases and confirmed cases show a peak in March and a decrease in July.
- Incident cases per 10⁵ inh. display a high peak in March.
- Case Fatality rate (%) chart shows a peak in March followed by a decrease.

Risk diagram and risk diagram (last 15 days) indicate a decrease in risk from March to July.
Israel 14-07-2020. Pop: 8.7M. Cumulative incidence: 489/10^5
Japan 14-07-2020. Pop: 126.5M. Cumulative incidence: 18/10^5
South Korea 14-07-2020. Pop: 51.3M. Cumulative incidence: 26/10^5

- Cumulative confirmed cases vs. time (days)
- Cumulative confirmed deaths vs. time (days)
- Number of cases vs. time (days)
- Cases per 10^7 inhabitants vs. time (days)
- Incident observed cases vs. time (day)
- Incident cases per 10^5 inh. vs. time (day)
- Incident observed cases vs. time (day)
- Incident observed cases per 10^5 inh. vs. time (day)
- Actual \( \rho_y = 0.9 \)
- Case fatality rate (%) vs. time (day)
- Risk diagram
- Risk diagram (last 15 days)
Australia 14-07-2020. Pop: 25.5M. Cumulative incidence: 40/10^5
Malaysia 14-07-2020. Pop: 32.4M. Cumulative incidence: 27/10^5

![Graphs and diagrams showing cumulative confirmed cases, confirmed cases, estimated cases, incident observed cases, actual R_t, and risk diagrams for Malaysia on 14-07-2020.](image-url)
Andorra 14-07-2020. Pop: 0.1M. Cumulative incidence: 1114/10^5

- Cumulative confirmed cases
- Cumulative confirmed deaths
- Number of cases
- Cases per 10^5 inhabitants
- Incident observed cases
- Incident cases per 10^5 inh.
- Case Fatality rate (%)
- Active cases per 10^5 inh. (last 14 days)

Actual \( \rho_f = NA \)

Risk diagram

Risk diagram (last 15 days)
(3) Analysis and prediction of COVID-19 for Spain and its autonomous communities

Data updated on 14th July, data series built with the day of the symptoms’ onset, reliable until 6th July.

Spain 08-07-2020. Pop: 47.0M. Cumulative incidence: 587/10^5

Deaths series currently under revision

BIOCOC-20 Degree = 3

Incident cases per 10^5 inh.

Incident observed cases per 10^5 inh.

Risk diagram

Risk diagram (last 15 days)

Deaths series currently under revision

Actual $p_f = 1.0$

Deaths series currently under revision

BIOCOM-Cov2 Degree = 3

Risk diagram

Risk diagram (last 15 days)
Catalunya 08-07-2020. Pop: 7.7M. Cumulative incidence: 771/10^5

Deaths series currently under revision

Actual $p_T = 1.5$

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Castilla Leon 08-07-2020. Pop: 2.4M. Cumulative incidence: 1114/10^5

Deaths series currently under revision

Actual ρ_f = 0.8

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Castilla-La Mancha 08-07-2020. Pop: 2.0M. Cumulative incidence: 1106/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 3

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Andalucia 08-07-2020. Pop: 8.4M. Cumulative incidence: 202/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 2

Risk diagram

Risk diagram (last 15 days)
Euskadi 08-07-2020. Pop: 2.2M. Cumulative incidence: 668/10^5

Deaths series currently under revision

Actual $\rho_7 = 1.7$

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Galicia 08-07-2020. Pop: 2.7M. Cumulative incidence: 406/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 3

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Navarra 08-07-2020. Pop: 0.7M. Cumulative incidence: 1217/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 3

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Aragon 08-07-2020. Pop: 1.3M. Cumulative incidence: 547/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 6

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Extremadura 08-07-2020. Pop: 1.1M. Cumulative incidence: 537/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 3

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
La Rioja 08-07-2020. Pop: 0.3M. Cumulative incidence: 1265/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 2

Risk diagram

Risk diagram (last 15 days)
Murcia 08-07-2020. Pop: 1.5M. Cumulative incidence: 170/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 2

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Asturias 08-07-2020. Pop: 1.0M. Cumulative incidence: 238/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 1

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Baleares 08-07-2020. Pop: 1.1M. Cumulative incidence: 207/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 2

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
Cantabria 08-07-2020. Pop: 0.6M. Cumulative incidence: 406/10^5

Deaths series currently under revision

BIOCOM-Cov2 Degree = 2

Deaths series currently under revision

Risk diagram

Risk diagram (last 15 days)
(3) Analysis and prediction of COVID-19 for Italy and its regions

Data obtained from: https://github.com/pcm-dpc/COVID-19/tree/master/dati-andamento-nazionale
Italy 15-07-2020. Pop: 60.5M. Cumulative incidence: 403/10^5

[Graphs and charts showing cumulative confirmed cases, confirmed cases per 10^5, and incident observed cases for Italy on 15-07-2020.]

Actual $\rho$ = 1.0

BIOCOM-Cov2 Degree = 2

Risk diagram

Risk diagram (last 15 days)

BIOCOM-Cov2 Degree = 3

Actual $\rho_f = 0.9$

![Graphs showing cumulative confirmed cases and deaths, along with incident observed cases and incident cases per 10^5 inh.](image)

**Actual $p_f = 1.1**

![Graph showing case fatality rate](image)

**Risk diagram**

![Risk diagram (last 15 days)](image)

[Graphs showing cumulative cases and deaths, confirmed cases, and predicted cases with time (days) on the x-axis and cumulative numbers on the y-axis.]

Incident observed cases

[Graph showing incident observed cases with time (day) on the x-axis and incident cases per 10^3 inh. on the y-axis.]

Actual \( \rho_7 = 1.2 \)

[Graph showing actual \( \rho_7 \) with time (day) on the x-axis and case fatality rate (%) on the y-axis.]

Risk diagram

[Graph showing active cases per 10^5 inh. (last 14 days) with risk levels indicated for July 15 and March 11.]

Risk diagram (last 15 days)

[Graph showing active cases per 10^5 inh. (last 14 days) with risk levels indicated for July 15, June 30, and other dates.]
Trento 15-07-2020. Pop: 0.5M. Cumulative incidence: 907/10^5

BIOCOM-Cov2 Degree = 2

Risk diagram

Risk diagram (last 15 days)

[Graphs and charts showing cumulative confirmed cases, confirmed cases per 10^5 inhabitants, and incident observed cases per 10^3 inh. over time.]

Actual ρ_T = NA

[BIOCOM-Cov2 Degree = 1]

[Risk diagram and Risk diagram (last 15 days)]
Umbria 15-07-2020. Pop: 0.9M. Cumulative incidence: 165/10^5

- Cumulative confirmed cases vs. time (days)
- Cumulative confirmed deaths vs. time (days)
- Number of cases and confirmed cases vs. time (day)
- Incidence observed cases vs. time (day)
- Incident cases per 10^3 inh. vs. time (day)
- Actual \( \rho_f \) = NA
- Case fatality rate (%) vs. time (day)
- Risk diagram
- Risk diagram (last 15 days)

July 15
March 19

July 15
June 30

Cumulative confirmed cases

Cumulative confirmed deaths

Number of cases

Cases per 10^5 inhabitants

Incident observed cases

Incident cases per 10^3 inh.

Incident observed cases

Incident observed cases per 10^3 inh.

Actual $r_f = 9.4$

Case fatality rate (%)

Risk diagram

Risk diagram (last 15 days)
Molise 15-07-2020. Pop: 0.3M. Cumulative incidence: 146/10⁵
Basilicata 15-07-2020. Pop: 0.6M. Cumulative incidence: 72/10^5

- Cumulative confirmed cases over time (days).
- Incidence observed cases over time (days).
- Actual $p_f = NA$.
- Case fatality rate over time (days).
- Risk diagram.

- BIOCOM-Cov2 Degree = 0.
Methods

(1) Data source

Data are daily obtained from World Health Organization (WHO) surveillance reports\(^1\), from European Centre for Disease Prevention and Control (ECDC)\(^2\) and from Ministerio de Sanidad\(^3\). These reports are converted into text files that can be processed for subsequent analysis. Daily data comprise, among others: total confirmed cases, total confirmed new cases, total deaths, total new deaths. It must be considered that the report is always providing data from previous day. In the document we use the date at which the datapoint is assumed to belong, i.e., report from 15/03/2020 is giving data from 14/03/2020, the latter being used in the subsequent analysis.

(2) Data processing and plotting

Data are initially processed with Matlab in order to update timeseries, i.e., last datapoints are added to historical sequences. These timeseries are plotted for EU individual countries and for the UE as a whole:

- Number of cumulated confirmed cases, in blue dots
- Number of reported new cases
- Number of cumulated deaths

Then, two indicators are calculated and plotted, too:

- Number of cumulated deaths divided by the number of cumulated confirmed cases, and reported as a percentage; it is an indirect indicator of the diagnostic level.
- \( \rho \): this variable is related with the reproduction number, i.e., with the number of new infections caused by a single case. It is evaluated as follows for the day before last report \((t-1)\):

\[
\rho(t-1) = \frac{N_{new}(t) + N_{new}(t-1) + N_{new}(t-2)}{N_{new}(t-5) + N_{new}(t-6) + N_{new}(t-7)}
\]

where \(N_{new}(t)\) is the number of new confirmed cases at day \(t\).

(3) Classification of countries according to their status in the epidemic cycle

The evolution of confirmed cases shows a biphasic behaviour:

(I) an initial period where most of the cases are imported;

(II) a subsequent period where most of new cases occur because of local transmission.

Once in the stage II, mathematical models can be used to track evolutions and predict tendencies. Focusing on countries that are on stage II, we classify them in three groups:

- Group A: countries that have reported more than 100 cumulated cases for 10 consecutive days or more;
- Group B: countries that have reported more than 100 cumulated cases for 7 to 9 consecutive days;
- Group C: countries that have reported more than 100 cumulated cases for 4 to 6 days.

---

\(^{1}\) https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
(4) Fitting a mathematical model to data

Previous studies have shown that Gompertz model\textsuperscript{4} correctly describes the Covid-19 epidemic in all analysed countries. It is an empirical model that starts with an exponential growth but that gradually decreases its specific growth rate. Therefore, it is adequate for describing an epidemic that is characterized by an initial exponential growth but a progressive decrease in spreading velocity provided that appropriate control measures are applied.

Gompertz model is described by the equation:

$$ N(t) = K e^{-\ln\left(\frac{K}{N_0}\right) e^{-a(t-t_0)}} $$

where \( N(t) \) is the cumulated number of confirmed cases at \( t \) (in days), and \( N_0 \) is the number of cumulated cases the day at day \( t_0 \). The model has two parameters:

\begin{itemize}
  \item \( a \) is the velocity at which specific spreading rate is slowing down;
  \item \( K \) is the expected final number of cumulated cases at the end of the epidemic.
\end{itemize}

This model is fitted to reported cumulated cases of the UE and of countries in stage II that accomplish two criteria: 4 or more consecutive days with more than 100 cumulated cases, and at least one datapoint over 200 cases. Day \( t_0 \) is chosen as that one at which \( N(t) \) overpasses 100 cases. If more than 15 datapoints that accomplish the stated criteria are available, only the last 15 points are used. The fitting is done using Matlab’s Curve Fitting package with Nonlinear Least Squares method, which also provides confidence intervals of fitted parameters \( (a \text{ and } K) \) and the \( R^2 \) of the fitting. At the initial stages the dynamics is exponential and \( K \) cannot be correctly evaluated. In fact, at this stage the most relevant parameter is \( a \). Fitted curves are incorporated to plots of cumulative reported cases with a dashed line. Once a new fitting is done, two plots are added to the country report:

\begin{itemize}
  \item Evolution of fitted \( a \) with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out;
  \item Evolution of fitted \( K \) with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out; if lower error bar indicates a value that is lower than current number of cases, the error bar is truncated.
\end{itemize}

These plots illustrate the increase in fittings’ confidence, as fitted values progressively stabilize around a certain value and error bars get smaller when the number of datapoints increases. In fact, in the case of countries, they are discarded and set as “Not enough data” if \( a>0.2 \text{ day}^{-1} \), if \( K>10^6 \) or if the error in \( K \) overpasses \( 10^6 \).

It is worth to mention that the simplicity of this model and the lack of previous assumptions about the Covid-19 behaviour make it appropriate for universal use, i.e., it can be fitted to any country independently of its socioeconomic context and control strategy. Then, the model is capable of quantifying the observed dynamics in an objective and standard manner and predicting short-term tendencies.

(5) Using the model for predicting short-term tendencies

The model is finally used for a short-term prediction of the evolution of the cumulated number of cases. The predictions increase their reliability with the number of datapoints used in the fitting. Therefore, we consider three levels of prediction, depending on the country:

\begin{itemize}
\end{itemize}

\textsuperscript{4} Madden LV. Quantification of disease progression. Protection Ecology 1980; 2: 159-176.
• Group A: prediction of expected cumulated cases for the following 3-5 days;
• Group B: prediction of expected cumulated cases for the following 2 days;
• Group C: prediction of expected cumulated cases for the following day.

The confidence interval of predictions is assessed with the Matlab function `predint`, with a 99% confidence level. These predictions are shown in the plots as red dots with corresponding error bars, and also gathered in the attached table. For series longer than 9 timepoints, last 3 points are weighted in the fitting so that changes in tendencies are well captured by the model.

(6) Estimating non-diagnosed cases

Lethality of Covid-19 has been estimated at around 1% for Republic of Korea and the Diamond Princess cruise. Besides, median duration of viral shedding after Covid-19 onset has been estimated at 18.5 days for non-survivors\(^6\) in a retrospective study in Wuhan. These data allow for an estimation of total number of cases, considering that the number of deaths at certain moment should be about 1% of total cases 18.5 days before. This is valid for estimating cases of countries at stage II, since in stage I the deaths would be mostly due to the incidence at the country from which they were imported. We establish a threshold of 50 reported cases before starting this estimation.

Reported deaths are passed through a moving average filter of 5 points in order to smooth tendencies. Then, the corresponding number of cases is found assuming the 1% lethality. Finally, these cases are distributed between 18 and 19 days before each one.

---

\(^5\) At this moment we are testing predictions at 4 days for countries with more than 100 cumulated cases for 13-15 consecutive days, and 5 days for 16 or more days.