Outbreaks of coronavirus COVID-19

George S. Androulakis ¹, Eleni G. Lisgara ¹, Silas G. Androulakis ² and George I. Karolidis ¹

¹ Department of Business Administration, University of Patras, GR 265.04, Greece.
² Department of Chemical Engineering, University of Patras, GR 265.04, Greece.

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## Contents

1 Introduction ...................................................................................... 7

### I An overview

2 Global cases .................................................................................. 11
  2.1 The confirmed and death graphs ........................................ 11
  2.2 Estimation for future maximum ........................................... 11
  2.3 Estimation of the number of cases ....................................... 12

3 The phenomenon is declined ......................................................... 15
  3.1 South Korea ............................................................................ 15
  3.2 China ......................................................................................... 16
    3.2.1 China Anhui ..................................................................... 16
    3.2.2 China Beijing ................................................................... 17
    3.2.3 China Chongqing ............................................................ 17
    3.2.4 China Guangdong ............................................................ 18
    3.2.5 China Henan .................................................................... 18
    3.2.6 China Hubei ..................................................................... 19
    3.2.7 China Hunan ..................................................................... 20
    3.2.8 China Jiangsu ................................................................... 20
    3.2.9 China Jiangxi ..................................................................... 20
    3.2.10 China Shandong .............................................................. 21
    3.2.11 China Sichuan ................................................................. 21
    3.2.12 China Zhejiang ............................................................... 21
  3.3 Cruise Ship Diamond Princess ................................................. 22
<table>
<thead>
<tr>
<th>II</th>
<th>Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Africa</td>
</tr>
<tr>
<td>4.1</td>
<td>Algeria</td>
</tr>
<tr>
<td>4.2</td>
<td>Egypt</td>
</tr>
<tr>
<td>4.3</td>
<td>South Africa</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Asia</td>
</tr>
<tr>
<td>5.1</td>
<td>China</td>
</tr>
<tr>
<td>5.1.1</td>
<td>China Beijing (2nd period)</td>
</tr>
<tr>
<td>5.1.2</td>
<td>China Hong Kong</td>
</tr>
<tr>
<td>5.2</td>
<td>India</td>
</tr>
<tr>
<td>5.3</td>
<td>Indonesia</td>
</tr>
<tr>
<td>5.4</td>
<td>Iran</td>
</tr>
<tr>
<td>5.5</td>
<td>Iraq</td>
</tr>
<tr>
<td>5.6</td>
<td>Israel</td>
</tr>
<tr>
<td>5.7</td>
<td>Japan</td>
</tr>
<tr>
<td>5.8</td>
<td>Malaysia</td>
</tr>
<tr>
<td>5.9</td>
<td>Pakistan</td>
</tr>
<tr>
<td>5.10</td>
<td>Philippines</td>
</tr>
<tr>
<td>5.11</td>
<td>Qatar</td>
</tr>
<tr>
<td>5.12</td>
<td>Saudi Arabia</td>
</tr>
<tr>
<td>5.13</td>
<td>Singapore</td>
</tr>
<tr>
<td>5.14</td>
<td>South Korea 2nd period</td>
</tr>
<tr>
<td>5.15</td>
<td>Thailand</td>
</tr>
<tr>
<td>5.16</td>
<td>Turkey</td>
</tr>
<tr>
<td>5.17</td>
<td>United Arab Emirates</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IV</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Australia</td>
</tr>
<tr>
<td>6.1</td>
<td>Australia</td>
</tr>
<tr>
<td>6.1.1</td>
<td>Australia New South Wales</td>
</tr>
<tr>
<td>6.1.2</td>
<td>Australia Queensland</td>
</tr>
<tr>
<td>6.1.3</td>
<td>Australia Victoria</td>
</tr>
<tr>
<td>6.2</td>
<td>New Zealand</td>
</tr>
</tbody>
</table>
### Europe

<table>
<thead>
<tr>
<th>Section</th>
<th>Country</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Austria</td>
<td>47</td>
</tr>
<tr>
<td>7.1</td>
<td>Belgium</td>
<td>48</td>
</tr>
<tr>
<td>7.2</td>
<td>Croatia</td>
<td>49</td>
</tr>
<tr>
<td>7.3</td>
<td>Czechia</td>
<td>49</td>
</tr>
<tr>
<td>7.4</td>
<td>Denmark</td>
<td>50</td>
</tr>
<tr>
<td>7.5</td>
<td>Estonia</td>
<td>50</td>
</tr>
<tr>
<td>7.6</td>
<td>Finland</td>
<td>51</td>
</tr>
<tr>
<td>7.7</td>
<td>France</td>
<td>51</td>
</tr>
<tr>
<td>7.8</td>
<td>Germany</td>
<td>52</td>
</tr>
<tr>
<td>7.9</td>
<td>Greece</td>
<td>53</td>
</tr>
<tr>
<td>7.10</td>
<td>Iceland</td>
<td>53</td>
</tr>
<tr>
<td>7.11</td>
<td>Ireland</td>
<td>54</td>
</tr>
<tr>
<td>7.12</td>
<td>Italy</td>
<td>54</td>
</tr>
<tr>
<td>7.13</td>
<td>Luxembourg</td>
<td>55</td>
</tr>
<tr>
<td>7.14</td>
<td>Netherlands</td>
<td>55</td>
</tr>
<tr>
<td>7.15</td>
<td>Norway</td>
<td>56</td>
</tr>
<tr>
<td>7.16</td>
<td>Poland</td>
<td>57</td>
</tr>
<tr>
<td>7.17</td>
<td>Portugal</td>
<td>57</td>
</tr>
<tr>
<td>7.18</td>
<td>Romania</td>
<td>58</td>
</tr>
<tr>
<td>7.19</td>
<td>Russia</td>
<td>58</td>
</tr>
<tr>
<td>7.20</td>
<td>Serbia</td>
<td>59</td>
</tr>
<tr>
<td>7.21</td>
<td>Slovenia</td>
<td>59</td>
</tr>
<tr>
<td>7.22</td>
<td>Spain</td>
<td>60</td>
</tr>
<tr>
<td>7.23</td>
<td>Sweden</td>
<td>61</td>
</tr>
<tr>
<td>7.24</td>
<td>Switzerland</td>
<td>61</td>
</tr>
<tr>
<td>7.25</td>
<td>United Kingdom</td>
<td>62</td>
</tr>
</tbody>
</table>

### North America

<table>
<thead>
<tr>
<th>Section</th>
<th>Country</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Canada</td>
<td>67</td>
</tr>
<tr>
<td>8.1</td>
<td>Canada Alberta</td>
<td>68</td>
</tr>
<tr>
<td>8.1.1</td>
<td>Canada British Columbia</td>
<td>68</td>
</tr>
<tr>
<td>8.1.2</td>
<td>Canada Ontario</td>
<td>68</td>
</tr>
<tr>
<td>8.1.3</td>
<td>Canada Quebec</td>
<td>69</td>
</tr>
<tr>
<td>8.2</td>
<td>Dominican Republic</td>
<td>69</td>
</tr>
<tr>
<td>8.3</td>
<td>Mexico</td>
<td>70</td>
</tr>
<tr>
<td>8.4</td>
<td>Panama</td>
<td>70</td>
</tr>
</tbody>
</table>
## South America

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>South America</td>
<td>75</td>
</tr>
<tr>
<td>9.1</td>
<td>Argentina</td>
<td>75</td>
</tr>
<tr>
<td>9.2</td>
<td>Brazil</td>
<td>76</td>
</tr>
<tr>
<td>9.3</td>
<td>Chile</td>
<td>76</td>
</tr>
<tr>
<td>9.4</td>
<td>Colombia</td>
<td>77</td>
</tr>
<tr>
<td>9.5</td>
<td>Ecuador</td>
<td>77</td>
</tr>
<tr>
<td>9.6</td>
<td>Peru</td>
<td>78</td>
</tr>
</tbody>
</table>

## Conclusion and Further Research

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Conclusion</td>
<td>81</td>
</tr>
</tbody>
</table>
The number of coronavirus cases per day is a time series. Time series analysis comprises methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data. Time series forecasting is the use of a model to predict future values based on previously observed values. Since many forecasting methodologies are value-oriented, it is essential to focus on point-oriented methods in order to forecast not the future value of the time series, but the future time that its optima will occur, (Androulakis & Lisgara, 2007; Lisgara, Karolidis, & Androulakis, 2010a, 2010b, 2012). These methodologies are based on nonlinear optimization techniques. Specifically, in this kind of techniques, time series is treated as an objective function subject to the factors affecting its future values. Thus, these point-oriented techniques are very accurate in predicting the time when the future extreme will occur.

This work uses the point-oriented technique provided by Lisgara, Karolidis & Androulakis, (Lisgara et al., 2010b), in order to predict the period of time at which the COVID-19 outbreaks peak. Then, for this period provided by the point-oriented technique, value-oriented methods are applied in order to approximate the number of cases that will occur until the predicted period. In this work were used data recorded until March 21st (Dong, Du, & Gardner, 2020).

Let’s focus on the time series defined by the number of cases of coronavirus per day. This series initially follows an exponentially increasing course, then this growth rate gradually slows down and the number of coronavirus cases peaked (takes its maximum value). Then the number of cases follows an exponential declining course and eventually the number of cases becomes zero. This ascending-peaked-descending path of the multitude virus outbreaks is defined as a period of the phenomenon. If this cycle is plotted on a graph

\[^1\text{A time series is a series of data points indexed (or listed or graphed) in time order. Most commonly, a time series is a sequence taken at successive equally spaced points in time}\]

\[^2\text{For quantitative estimation of cases an exponential or an ARIMA (Autoregressive Integrated Moving Average) prediction model can be applied, (Brockwell & Davis, 2016; Durbin & Koopman, 2012; Hyndman & Khandakar, 2007; R Development Core Team 3.6.2., 2019). Note that these numerical predictions become unreliable as we move away from the time of calculation.}\]
where the x-axis is time, it looks like a bell (red and blue curves below).

The control of the peak time is important to ensure that the healthcare system does not exceed its capacity. Let’s assume that the number of cases that are about to occur is constant. Only the range of the period changes. Note that when extending the period (see blue and red curves in the figure above), this results in a lower maximum value (blue curve). Therefore, fewer cases are occurring per day and consequently less serious incidents per day. Also note that this reduction in the maximum number of cases will result in the delay of disease’s peak. Therefore, the people who were in the red area will spread to the blue area, so, they will get sick, but this will happen over a longer period of time. Thus: (a) scientists are given more time to find the drug for the disease, and (b) there is a prolongation of the phenomenon towards the end of the spring, as the weather gets warmer, and then there is hope that the spread of the virus will slow.
I

An overview

2  Global cases ..........................  11
2.1  The confirmed and death graphs
2.2  Estimation for future maximum
2.3  Estimation of the number of cases

3  The phenomenon is declined ..............  15
3.1  South Korea
3.2  China
3.3  Cruise Ship Diamond Princess
2. Global cases

All graphs were based on the number of new cases per day until March 30th.

2.1 The confirmed and death graphs

In these two graphs:

- Confirmed graph refers to the number of cases reported each day. Graphs are made for regions/countries that have more than 500 cases in total.
- Deaths graph refers to the number of deaths reported each day. Graphs are made for regions/countries that have more than 100 deaths in total.
- Labels above each dot indicate the number per day. Red font denotes the days where the curvature is like u and blue when is inverted u.
- If a cyan area appears between two dates in the graph, it refers to a period of Phase 1 measures\(^1\).
- The yellow area between two dates in the graph renders the period of mild mitigation measures and that would be Phase 2\(^2\).
- Finally, the pink area between two dates in the graph shows the critical period of draconian measures, and that would be Phase 3\(^3\).

2.2 Estimation for future maximum

For the approximation of the interval that the maximum is expected to appear, is employed the algorithm provided by Lisgara, Karolidis & Androulakis, (Lisgara et al., 2010b).

The procedure is approximate; so as the phenomenon evolves and the time series acquires more data, the approximated interval may slightly move and narrow.

\(^1\)closed schools and universities.
\(^2\)some business closure, gathering restrictions, travel restrictions (i.e. reduced flights, public transport and route restrictions), voluntary home quarantine, partial lockdown, etc.
\(^3\)the extreme mitigation step known as “suppression” or “lockdown”; ban on all non essential transport and movement across the country, closed physical retail businesses except for those providing essential services, like grocery and food stores, and pharmacies.
Chapter 2. Global cases

For instance, on day zero of the constrictive measures imposition the only known points are the past ones, that actually correspond to a period without measures. As the phenomenon evolutes and the restrictive measures work, the approximation of the day that the maximum will appear is expected to move some days later and affecting the forecast.

2.3 Estimation of the number of cases

Suppose the estimate for the future maximum is between $t_1$ and $t_2$. Then, the two ends of the interval $[a, b]$ for the number of cases are calculated as follows:

- $a$ the lower bound of the interval given by the ARIMA model for $t_1$ days,
- $b$ the upper bound of the interval given by the ARIMA model for $t_2$ days.

The focus is on the number of cases per day $^4$, (Peterson & Carl, 2020; R Development Core Team 3.6.2., 2019):

When comparing with the previous forecasts, a minor displacement of the peak point is observed due to the following reasons:

- the gradual integration of high population areas, such as the US,
- the imposition of constrictive measures on most countries is in progress,
- the increase of outbreaks in the southern hemisphere due to the oncoming winter that favours the virus spread.

$^4$The Cullen & Frey (Cullen, Frey, & Frey, 1999; Delignette-Muller & Dutang, 2015) was used for the provision of the visual estimation of the coronavirus cases evolution. When the phenomenon is at the beginning the red dot lies bellow and to the right of the graph (near to the symbol $\otimes$ at the bottom right of the figure indicating the exponential distribution) but when it declines then it moves up to the left of the graph (near to the * indicates the normal distribution).
2.3 Estimation of the number of cases

Estimation for future maximum after 32 – 40 days

Estimation of number of cases: ARIMA [44002, 995353]
3. The phenomenon is declined

3.1 South Korea

Let’s see what the case of South Korea, where a first cycle of the phenomenon has been observed, shows.

<table>
<thead>
<tr>
<th>South Korea (confirmed)</th>
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</thead>
<tbody>
<tr>
<td><strong>4 weeks period</strong></td>
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<tr>
<td>Estimation for future maximum after Estimation of number of cases: ARIMA</td>
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</table>

1. The uptrend started on February 19th and peaked on February 29th the first (813 cases) and on March 3rd the second (51 cases). Therefore, this growth course lasted 11 to 14 days.
2. The descending direction begins on March 4th and continues until March 15th, therefore it lasted about 12 days.

Remark 3.1 — South Korea. There has been a slight increase in the last seven days, which is alarming as this may indicate that a new outbreak is starting.
Chapter 3. The phenomenon is declined

Estimation for future maximum after 35 – 45 days
Estimation of number of cases: ARIMA [107, 1803]

Remark 3.2 — Curve of the number of deaths. Notice that the death-rate curve is still rising, while the incidence-rate curve has diminished.

3.2 China

3.2.1 China Anhui

Period: 4 weeks
Estimation of number of cases: ARIMA -
3.2 China

3.2.2 China Beijing

1st Period: 4 weeks
Estimation for future maximum (2nd period) after:
Estimation of number of cases: ARIMA

3.2.3 China Chongqing

Period: 5 weeks (probably)
Estimation of number of cases: ARIMA
3.2.4 China Guangdong

Apparently the area experiences the reappearance of the virus that is in progress.

3.2.5 China Henan

Period: 4 weeks (probably)
Estimation of number of cases: ARIMA
3.2 China

3.2.6 China Hubei

Apparenty it is the only area that a full cycle, in both number of confirmed cases and number of deaths, is complete. It is observed that the "death period" is almost double than the "confirmed cases" period.

Remark 3.3 Therefore, although the COVID-19 confirmed cases phenomenon tends to de-escalate, the COVID-19 deaths phenomenon is increasing almost until the number of confirmed cases eliminates.
3.2.7 China Hunan

<table>
<thead>
<tr>
<th>Period:</th>
<th>4 weeks</th>
</tr>
</thead>
<tbody>
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<td>Estimation of number of cases:</td>
<td>ARIMA -</td>
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</tbody>
</table>

3.2.8 China Jiangsu

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<tr>
<th>Period:</th>
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<tr>
<td>Estimation of number of cases:</td>
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</tbody>
</table>

3.2.9 China Jiangxi

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<thead>
<tr>
<th>Period:</th>
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</tr>
</thead>
<tbody>
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<td>Estimation of number of cases:</td>
<td>ARIMA -</td>
</tr>
</tbody>
</table>
3.2 China

3.2.10 China Shandong

Period: 4 weeks
Estimation of number of cases: ARIMA

3.2.11 China Sichuan

Period: 4 weeks
Estimation of number of cases: ARIMA

3.2.12 China Zhejiang

Period: 4 weeks (probably)
Estimation of number of cases: ARIMA
Remark 3.4 Probably the area experiences the reappearance of the virus.

3.3 Cruise Ship Diamond Princess

| Period: 3 weeks |
| Estimation of number of cases: ARIMA - |
II

4 Africa ............................. 25
4.1 Algeria
4.2 Egypt
4.3 South Africa
4. Africa

4.1 Algeria

<table>
<thead>
<tr>
<th>Estimation for future maximum after</th>
<th>8 – 16 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation of number of cases:</td>
<td>ARIMA [511, 7792]</td>
</tr>
</tbody>
</table>
4.2 Egypt

Estimation for future maximum after 12 – 18 days
Estimation of number of cases: ARIMA [609, 7632]

4.3 South Africa

Estimation for future maximum after 16 – 22 days
Estimation of number of cases: ARIMA [1280, 29943]
5. Asia

5.1 China

5.1.1 China Beijing (2nd period)

<table>
<thead>
<tr>
<th>1st Period:</th>
<th>4 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation for future maximum (2nd period) after:</td>
<td></td>
</tr>
<tr>
<td>Estimation of number of cases: ARIMA</td>
<td></td>
</tr>
</tbody>
</table>
5.1.2 China Hong Kong

Estimation for future maximum after 18 – 26 days
Estimation of number of cases: ARIMA [641, 19487]

5.2 India

Estimation for future maximum after 11 – 19 days
Estimation of number of cases: ARIMA [5242, 21345]
5.3 Indonesia

Estimation for future maximum after 16 – 22 days  
Estimation of number of cases: ARIMA [1465, 19689]

5.4 Iran

Estimation for future maximum after 10 – 16 days  
Estimation of number of cases: ARIMA [64946, 424691]

In Iran, during the last 4 days is observed a new "attack" of the virus; in fact, a large
increase of the confirmed cases is happening after a long period of 10-12 days that were thought to be the peak of the phenomenon.

5.5 Iraq

| Estimation for future maximum after | 24 – 30 days |
| Estimation of number of cases: ARIMA | [5287, 27583] |
5.6 Israel

Estimation for future maximum after 9 – 15 days
Estimation of number of cases: ARIMA [4247, 99754]

In Israel, Phase 1 measures were imposed on March 14th and Phase 3 measures on March 19th. A slight hold back on the exponential growth rate of the confirmed cases is observed.

5.7 Japan

Estimation for future maximum after 9 – 13 days
Estimation of number of cases: ARIMA [3779, 34044]

In Japan, Phase 1 measures were imposed on March 2nd. For a comparatively long period of 4 weeks, the COVID-19 confirmed cases trend has increased only moderately.
5.8 Malaysia

Estimation for future maximum after 8 – 12 days
Estimation of number of cases: ARIMA [3501, 29674]

5.9 Pakistan

Estimation for future maximum after 11 – 17 days
Estimation of number of cases: ARIMA [1597, 23770]
5.10 Philippines

Estimation for future maximum after 13 – 20 days
Estimation of number of cases: ARIMA [1547, 66728]

5.11 Qatar

Estimation for future maximum after 15 – 25 days
Estimation of number of cases: ARIMA [1261, 3168]
5.12 Saudi Arabia

<table>
<thead>
<tr>
<th>Estimation for future maximum after</th>
<th>12 – 18 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation of number of cases: ARIMA</td>
<td>[1299, 21548]</td>
</tr>
</tbody>
</table>

5.13 Singapore

<table>
<thead>
<tr>
<th>Estimation for future maximum after</th>
<th>11 – 17 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation of number of cases: ARIMA</td>
<td>[1692, 11357]</td>
</tr>
</tbody>
</table>
5.14 South Korea 2nd period

4 weeks period

Estimation for future maximum after 24 - 30 days
Estimation of number of cases: ARIMA [7166, 9743]

5.15 Thailand

Estimation for future maximum after 11 – 15 days
Estimation of number of cases: ARIMA [1388, 34487]
5.16 Turkey

Estimation for future maximum after 11 – 15 days
Estimation of number of cases: ARIMA [9217, 216347]

5.17 United Arab Emirates

Estimation for future maximum after 11 – 17 days
Estimation of number of cases: ARIMA [131, 3923]
Australia

6 Australia ......................... 41
6.1 Australia
6.2 New Zealand
6. Australia

6.1 Australia

<table>
<thead>
<tr>
<th>Estimation for future maximum after</th>
<th>36 – 42 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation of number of cases: ARIMA</td>
<td>[3984, 153287]</td>
</tr>
</tbody>
</table>
6.1.1 Australia New South Wales

Estimation for future maximum after 20 – 28 days
Estimation of number of cases: ARIMA [4305, 47263]

6.1.2 Australia Queensland

Estimation for future maximum after 20 – 28 days
Estimation of number of cases: ARIMA [1479, 14571]

6.1.3 Australia Victoria

Estimation for future maximum after 16 – 22 days
Estimation of number of cases: ARIMA [621, 16712]
6.2 New Zealand

Estimation for future maximum after 8 – 14 days
Estimation of number of cases: ARIMA [514, 9305]
7 Europe .......................... 47
7.1 Austria
7.2 Belgium
7.3 Croatia
7.4 Czechia
7.5 Denmark
7.6 Estonia
7.7 Finland
7.8 France
7.9 Germany
7.10 Greece
7.11 Iceland
7.12 Ireland
7.13 Italy
7.14 Luxembourg
7.15 Netherlands
7.16 Norway
7.17 Poland
7.18 Portugal
7.19 Romania
7.20 Russia
7.21 Serbia
7.22 Slovenia
7.23 Spain
7.24 Sweden
7.25 Switzerland
7.26 United Kingdom
7. Europe

7.1 Austria

In Austria the imposition of Phase 3 measures on March 3rd did not change the dynamics of the exponential growth rate the cases follow.
7.2 Belgium

In Belgium the imposition of Phase 2 measures on March 18th did change the dynamics of the exponential growth rate of the confirmed cases for two days, March 23rd and 24th.
### 7.3 Croatia

**Estimation for future maximum after** 15 – 21 days  
**Estimation of number of cases:** ARIMA [713, 12356]

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### 7.4 Czechia

**Estimation for future maximum after** 12 – 18 days  
**Estimation of number of cases:** ARIMA [2817, 50246]

In the Czech Republic the imposition of Phase 3 measures on March 15\textsuperscript{th} did change the dynamics of the exponential growth rate of the confirmed cases for three days, from March the 21\textsuperscript{st} until the 23\textsuperscript{rd}. 
### 7.5 Denmark

| Estimation for future maximum after | 11 – 15 days |
| Estimation of number of cases: ARIMA | [2395, 38165] |

### 7.6 Estonia

| Estimation for future maximum after | 8 – 14 days |
| Estimation of number of cases: ARIMA | [679, 8511] |
7.7 Finland

Estimation for future maximum after 8 – 12 days
Estimation of number of cases: ARIMA [2160, 15675]

In Finland only Phase 1 measures were imposed.

7.8 France

Estimation for future maximum after 17 – 21 days
Estimation of number of cases: ARIMA [74074, 744950]

In France, Phase 3 measures were imposed on March 17th. However, the dynamics of the exponential growth rate of the confirmed cases changed for two days, March 21st and 22nd.
Estimation for future maximum after 30 – 34 days
Estimation of number of cases: ARIMA [2606, 90827]

7.9 Germany

Estimation for future maximum after 8 – 12 days
Estimation of number of cases: ARIMA [62095, 1039518]

In Germany the imposition of Phase 2 measures was immediate on March 22nd. Until now there is any change on the dynamics of the exponential growth rate of the confirmed cases.
7.10 Greece

Estimation for future maximum after 24 – 30 days
Estimation of number of cases: ARIMA [533, 22422]

7.11 Iceland

Estimation for future maximum after 14 – 20 days
Estimation of number of cases: ARIMA [406, 12735]
### 7.12 Ireland

**Estimation for future maximum after** 8 – 12 days  
**Estimation of number of cases:** ARIMA [1309, 30529]

In Ireland the Phase 1 measures were imposed on March 12th and seem to have slightly hold back the growth rate of the confirmed cases. Also, the imposition of Phase 3 measures on March 23rd may result to shift peak point by some days; the data to be collected during the next 3-4 days will contribute to a safer forecast.

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### 7.13 Italy

**Estimation for future maximum after** 3 – 7 days  
**Estimation of number of cases:** ARIMA [159279, 848012]

In Italy it is observed (a) that number of the COVID-19 confirmed cases per day is is reducing, and (b) the curvature tends to change. This is an indication that the exponential growth has suspended, and the phenomenon is at its peak or close to it.
7.14 Luxembourg

Estimation for future maximum after 11 – 17 days
Estimation of number of cases: ARIMA [20684, 118468]

7.15 Netherlands

Estimation for future maximum after 9 – 13 days
Estimation of number of cases: ARIMA [24915, 126206]
Chapter 7. Europe

Estimation for future maximum after 11 – 17 days
Estimation of number of cases: ARIMA [2702, 12823]

7.16 Norway

Estimation for future maximum after 3 – 11 days
Estimation of number of cases: ARIMA [5823, 35124]

In Norway, only Phase 1 measures were imposed and there are some indications that the phenomenon is close to its peak. However, two of the latest observations form a u-curve, and that makes it unsafe to forecast.
7.17 Poland

Estimation for future maximum after 9 – 15 days
Estimation of number of cases: ARIMA [5466, 24303]

7.18 Portugal

Estimation for future maximum after 11 – 15 days
Estimation of number of cases: ARIMA [16530, 92223]

Estimation for future maximum after 13 – 20 days
Estimation of number of cases: ARIMA [119, 3097]
7.19 Romania

Estimation for future maximum after 17 – 21 days
Estimation of number of cases: ARIMA [1815, 4671]

7.20 Russia

Estimation for future maximum after 13 – 21 days
Estimation of number of cases: ARIMA [9320, 48418]
7.21 Serbia

Estimation for future maximum after 11 – 15 days
Estimation of number of cases: ARIMA [741, 9399]

7.22 Slovenia

Estimation for future maximum after 15 – 21 days
Estimation of number of cases: ARIMA [730, 14089]
7.23 Spain

Estimation for future maximum after $8 - 12$ days
Estimation of number of cases: ARIMA $[218282, 1116645]$

In Spain is observed that for a 5-day period the COVID-19 confirmed cases were reducing, while during the three later days the trend seems to form a u-curve. In many areas that the curve trend changed that change occurred 5-6 days days after the restriction measures, that is equal to the COVID-19 mean incubation period.

Estimation for future maximum after $14 - 20$ days
Estimation of number of cases: ARIMA $[6803, 167686]$
7.24 Sweden

Estimation for future maximum after 9 – 15 days
Estimation of number of cases: ARIMA [7242, 54472]

7.25 Switzerland

Estimation for future maximum after 3 – 6 days
Estimation of number of cases: ARIMA [14829, 111059]

In the United Kingdom, Phase 3 measures were imposed on March 23rd, while on March
the 29th the first sign of decline on the number of COVID-19 confirmed cases appeared, as a result of these measures.

7.26 United Kingdom

In the UK Phase 3 measures were implemented at March 23rd and at 29th there was the first evidence of decline as a result of these measures.
Estimation for future maximum after 20 – 28 days
Estimation of number of cases: ARIMA \([1228, 47121]\)
8 North America ..................... 67
8.1 Canada
8.2 Dominican Republic
8.3 Mexico
8.4 Panama
8.5 US
8. North America

8.1 Canada

<table>
<thead>
<tr>
<th>Estimation for future maximum after</th>
<th>9 – 15 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation of number of cases: ARIMA</td>
<td>[26611, 134398]</td>
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</tbody>
</table>
8.1.1 Canada Alberta

Estimation for future maximum after 16 – 22 days
Estimation of number of cases: ARIMA [621, 9562]

8.1.2 Canada British Columbia

Estimation for future maximum after 14 – 20 days
Estimation of number of cases: ARIMA [884, 16071]

8.1.3 Canada Ontario

Estimation for future maximum after 14 – 20 days
Estimation of number of cases: ARIMA [4075, 37354]
8.1.4 Canada Quebec

Estimation for future maximum after 16 – 22 days
Estimation of number of cases: ARIMA [2840, 86765]

8.2 Dominican Republic

Estimation for future maximum after 12 – 18 days
Estimation of number of cases: ARIMA [1860, 15980]
8.3 Mexico

Estimation for future maximum after 11 – 17 days
Estimation of number of cases: ARIMA [848, 21361]

8.4 Panama

Estimation for future maximum after 17 – 25 days
Estimation of number of cases: ARIMA [901, 32136]
Estimation for future maximum after 18 – 27 days
Estimation of number of cases: ARIMA [846389, 4175035]

Estimation for future maximum after 22 – 36 days
Estimation of number of cases: ARIMA [2467, 139244]
South America

9 South America .......................... 75
9.1 Argentina
9.2 Brazil
9.3 Chile
9.4 Colombia
9.5 Ecuador
9.6 Peru
9. South America

9.1 Argentina

<table>
<thead>
<tr>
<th>Estimation for future maximum after</th>
<th>17 – 25 days</th>
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<tr>
<td>Estimation of number of cases:</td>
<td>ARIMA [745, 18153]</td>
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In Argentina the imposition of Phase 3 measures on March 20th did not change the dynamics of the exponential growth rate the cases follow.
9.2 Brazil

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<tr>
<th>Estimation for future maximum after</th>
<th>14 – 20 days</th>
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<tbody>
<tr>
<td>Estimation of number of cases: ARIMA</td>
<td>[4256, 69208]</td>
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</table>

9.3 Chile

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<tr>
<th>Estimation for future maximum after</th>
<th>28 – 34 days</th>
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<tr>
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<td>[136, 5121]</td>
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</table>

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<tr>
<th>Estimation for future maximum after</th>
<th>19 – 25 days</th>
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<tbody>
<tr>
<td>Estimation of number of cases: ARIMA</td>
<td>[2139, 45220]</td>
</tr>
</tbody>
</table>
9.4 Colombia

Estimation for future maximum after 18 – 24 days
Estimation of number of cases: ARIMA [702, 14136]

9.5 Ecuador

Estimation for future maximum after 10 – 14 days
Estimation of number of cases: ARIMA [1924, 35456]

In Ecuador, although only Phase 1 measures were imposed, the exponential growth rate is not large.
9.6 Peru

Estimation for future maximum after 13 – 20 days
Estimation of number of cases: ARIMA [852, 21779]
The basic conclusions are:

1. The case of the regions/countries where the decline has occurred, do not reject the theoretical expectation that the time of escalation and decline is approximately the same.

2. In regions/countries where the phenomenon has completed a cycle, the cycle duration was approximately 4 weeks.

3. In the regions/countries where the cycle of the phenomenon is ongoing its duration looks like it has been extended.

4. It is observed that the ”death period” is almost double (7 weeks) than the ”confirmed cases” period (4 weeks).

Further research:

- in some areas, despite the imposition of mitigation measures, their impact was not expressed as a trend change on the COVID-19 confirmed cases curve
- however, in some areas the mitigation measures did affect the COVID-19 confirmed cases curve. In these cases what should be further approximated is the measures’ impact in terms of time shifting of the expected peak, and the qualitative reduction of maximum infected cases, as well.

How realistic is the above? Unfortunately, the “no free lunch theorem” leaves little room for generalization. Each case is unique, each problem has its own optimal solution, so we have to adapt better to it.


