MT3002 The Mathematics and Statistics of Infectious Disease Outbreaks Summer 2020 - Project 2

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Introduction

In 2020, the world has come to face the Corona pandemic. A virus that has challenged the healthcare and our way of living and during this first half of 2020, the media has constantly reported on the number of deaths of Covid-19 per day for each country. This project focuses on the Covid-19 statistics for European countries in the period January to July. We are going to study the time series of number of deaths and study the effect of interventions for some European countries as well as the reprodution number, we plot the percentage of deaths caused by Covid-19 in 2020 for each country and look at the mortality rate for this period compared to the same period previous years. Finally, we are going to study some statistics specific for Sweden.

Methods and Data

In this project we use data from ECDC (European Centre for Disease Prevention and Control) [7] who daily update data on Covid-19 deaths and infected for each day and country worldwide. Data of total number of deaths in 2020 is found from Eurostat [8, 9] were data on deaths per week and month is provided for each European country. For the analysis of Sweden, data from ECDC [7] and Eurostat [8] were used as well as data from Folkhälsomyndigheten [10] to obtain data for each county.

To perform the analysis, RStudio Version 1.1.463 was used together with visualisation and data cleaning packages such as `dplyr`, `tidyr`, `xml2`, `readr`, `readxl` , `rvest` for data cleaning and to read data into R and `EpiEstim`, `Hmisc`, `rworldmap`, `RColorBrewer` for data analysis and visualisation.

Results and Analysis

In this section we show the results from the data analysis made for different aspects of Covid-19 in Europe such as the reproduction number, the number and proportions of deaths for each country, excess mortality and number of deaths in each county in Sweden as well as excess mortality.

Covid-19 in Europe

To gain a better understanding of how the pandemic has affected Europe, we create plots that visualise the number of deaths in Europe. Added to the plots is the date that each country imposed a lockdown for a selected 16 countries based on the 10 most populated (Germany [4], United Kingdom [4], France [4], Italy [4], Spain [4], Ukraine [4], Poland [4], Romania [12], Netherlands [3] and Belgium [4]) and Scandinavia (Sweden, Norway [11], Denmark [14] and Finland [2]). The data is retrieved from European Centre for Disease Prevention and Control [7] and the time period is from January to July 2020. The countries are shown in alphabetical order.

Figure 1: Time series of Covid−19 deaths from January−July 2020
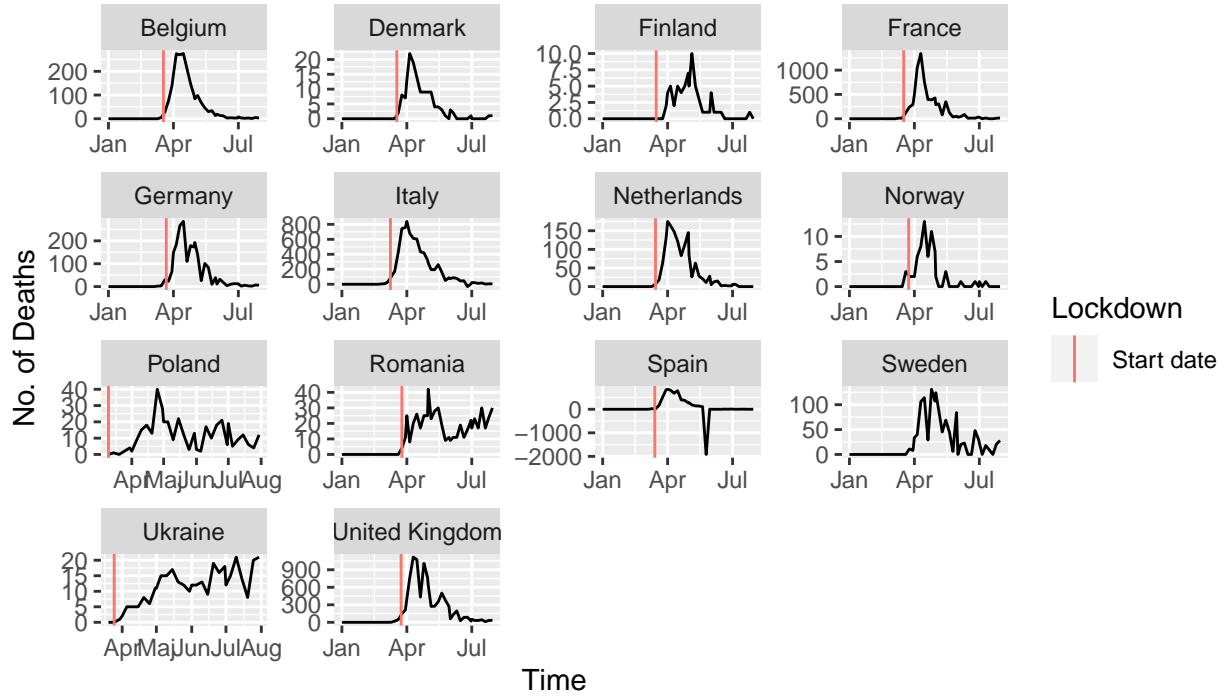
Studying the plots in Figure 1, we can observe that the largest increase of the number of deaths is between Mars and April. The peak of the number of deaths is hit somewhere in April for almost all countries with the exception of Romania and Ukraine which, looking at these graphs, have not yet reached their peaks. All of these countries have a lockdown, except for Sweden. The end dates of the lockdown are not added to the plots as these dates have not occurred yet, but can be added at a later time this year. Common for all countries is that the largest increase of the number of deaths is after the lockdown started.

The plot of the number of deaths in Spain shows a very large negative number in May. The date of this occurrence is shown in Table 1. The reason for this is not known, but it could be the case that the number of deaths were incorrectly reported so the numbers have to be evened out.

Table 1: Spain

Date	Country	Cases	Deaths
2020-05-25	Spain	-372	-1918

Reproduction number R_0

The reproduction number R_0 is a mesure of how infectious a disease is. It is the expected number of contacts that an infectious has with susceptibles which makes the susceptibles infected.

To calculate the reproduction number we must know the population size to find the observed fraction infected, that we denote by $\tilde{\tau}$, in this population, then we can calucalte the estimated $\hat{R}_0$ as defined in Lecture 4.

$$\hat{R}_0 = \frac{-\ln(1 - \tilde{\tau})}{\tilde{\tau}}$$

From ECDC [7] we have data on the number of infected people in Covid-19 for each country as well as the population for each country year 2019. By using this data we can calculate the reproducion number for a selection of European countries based on data from January to July in descending order.

Table 2: Reproduction number R0

| Country	R0	Country	R0
Sweden	1.003935	Romania	1.001279
Spain	1.003086	Germany	1.001259
Belgium	1.003050	Denmark	1.001184
United Kingdom	1.002275	Norway	1.000862
Italy	1.002053	Ukraine	1.000783
Netherlands	1.001564	Finland	1.000673
France	1.001395	Poland	1.000593

From Table 2 we can see that the reproduction number is almost the same for all the selected countries in Europe with a number close to 1 with Sweden at the top. Then we can say that based in this data and time period, the reproduction number of Covid-19 for these countries is 1.

Proportion of Covid-19 deaths

As was shown in the plots in Figure 1, the number of deaths differs by a large number for each country which is do to the very different number of inhabitants in each country. To better compare the European countries in terms of Covid-19 deaths this map below shows the proportion of total deaths from January to July 2020 that were caused by Covid-19. The number of total deaths was collected from Eurostat based on weekly deaths for this period and for each country [8].

**Figure 2: Proportion of deaths caused by Covid–19 from January to July 2020**
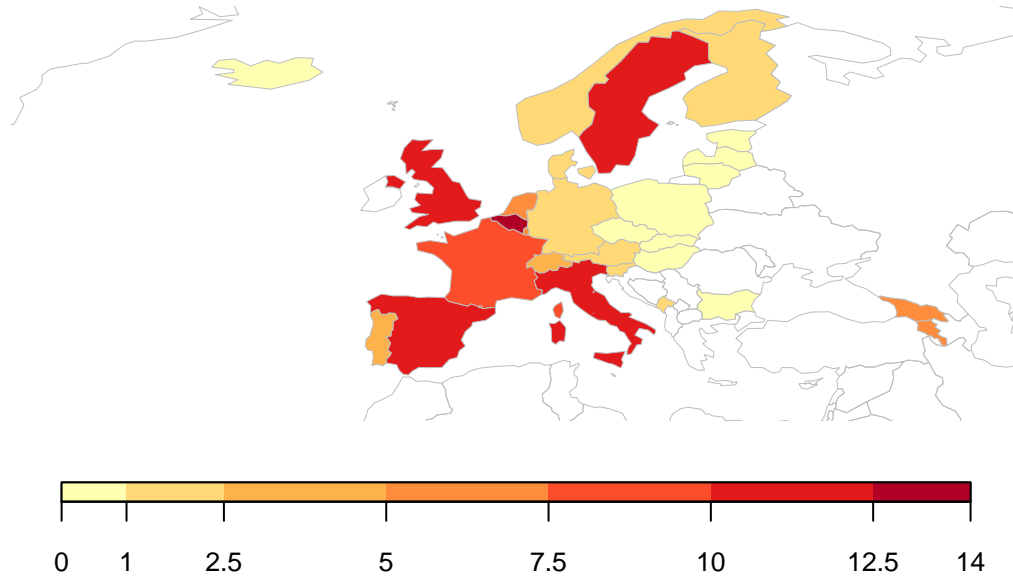
From the map we can observe that the countries with the highest proportion of Covid-19 deaths are Spain, United Kingdom, Italy, Sweden and Belgium with the largest proporiton, almost 14%! We can also observe that all of the Eastern European countries have very low proportions, between 0% and 1% and Sweden has by far the largest proportion in Scandinavia.
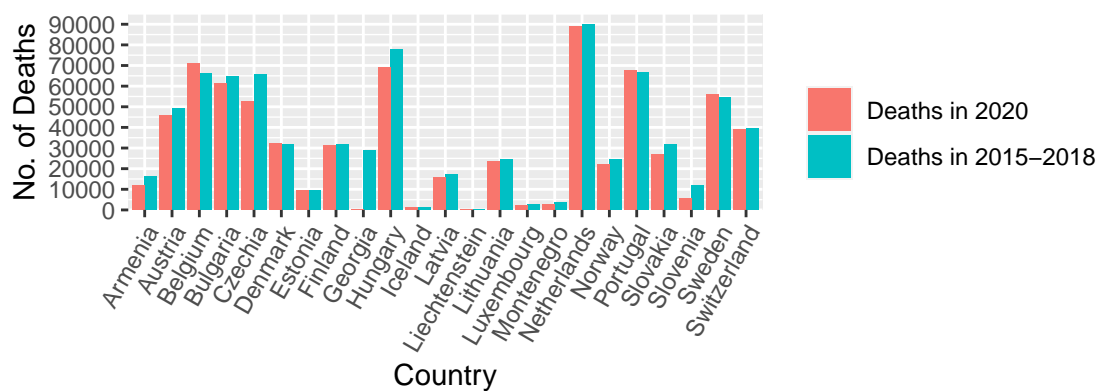
Excess Mortality

EuroMOMO, European mortality monitoring activity, is an organisation that measures excess deaths in Europe that are related to pandemics and influenzas and publish a weekly bulletin with their observations. In their Bulletin for week 31, that is the last week in July 2020, they wrote that the levels of mortality in Europe are going back to normal after observing an excess mortality earlier due to Covid-19 [6]. In this section we are going to study if these results published in EuroMOMO have support from our data. To do this, we use data of mortality from year 2015-2018 from the period January to July using data from Eurostat [9]. The reason for not using data up to 2019 is that there were missing data for some countries. Then we sum all the number of deaths for each year and divide by four to obtain an average number of deaths per year for each country. We plot these values together with the values form this time period for year 2020 for each country to then be able to observe if there is an excess mortality due to Covid-19. To make it easier to interpret the result, we put the five countries with the largest population and hence the largest amount of deaths in one graph and the rest of the countries together in another graph.

Figure 3: Mortality in most populated countries in Europe January–July 2020
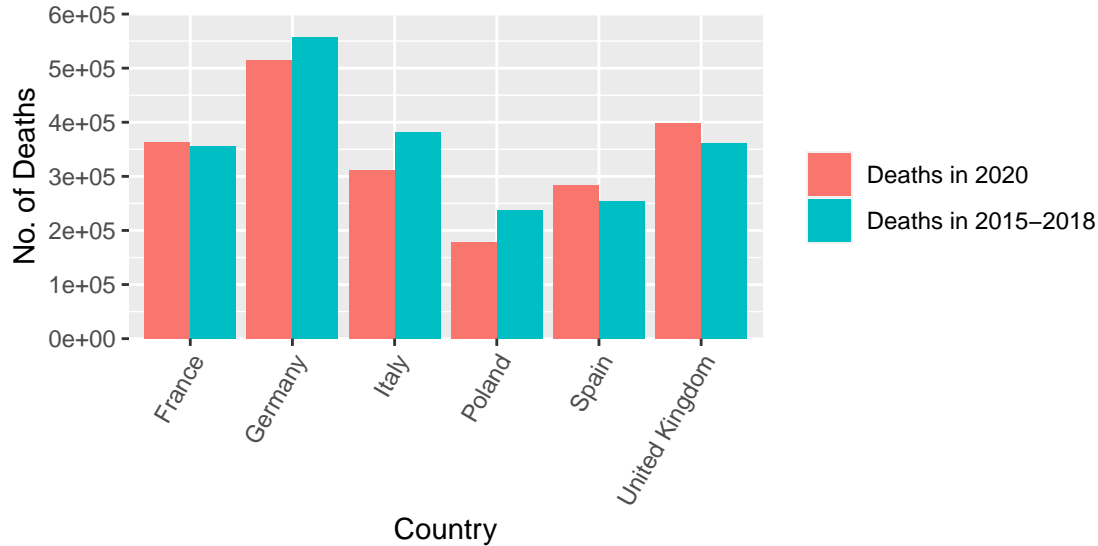
From Figure 3 we observe the number of deaths for France, Germany, Italy, Poland, Spain and United Kingdom for year 2020 and the average of year 2015-2018. From the plot we can observe that France, Spain and the United Kingdom have an excess mortality for year 2020. From the map showing the proportions of death cased by Covid-19 we observed that France, Spain and United Kingdom all had high proportions.

Figure 4: Mortality in Europe January–July 2020

In Figure 4 we observe the number of deaths for a number of European countries for which we had data for

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all years. From the plot we can observe that Belgium, Portugal and Sweden have an excess mortality in year 2020 compared to the average of 2015-2018. We can also observe that the mortality is almost at the same levels for the different years for Denmark, Finland, Estonia and Luxembourg. The remaining countries had a higher mortality in the average of the number of deaths between 2015 and 2018.

Excess mortality in Sweden

In Swedish Radio's news broadcast P1, August 12, 2020 [15] a demography statistician from SCB (Statistiska Centralbyrån) was interviewed to talk about the excess mortality in Sweden. In the news broadcast it was said that there has been an excess mortality in Sweden, and in Mars and April, the number of deaths were almost 50% higher than the average of the last five years but in July the number of deaths have been lower than usual which the statistician said is common in a Pandemic. Then on average for the whole year, looking at the the excess mortality between January and July, the mortality is sarting to approach normal values. To study if there is truth in this statement using data from Eurostat [9], we are going to plot the average number of deaths in Sweden from January-June between 2015 and 2019 together with the number of deaths from January to June in 2020 and then do the same but for January to July. We are also going to plot the mortality for Mars and April and see what the results are. The resulting plots are shown below.

Figure 5
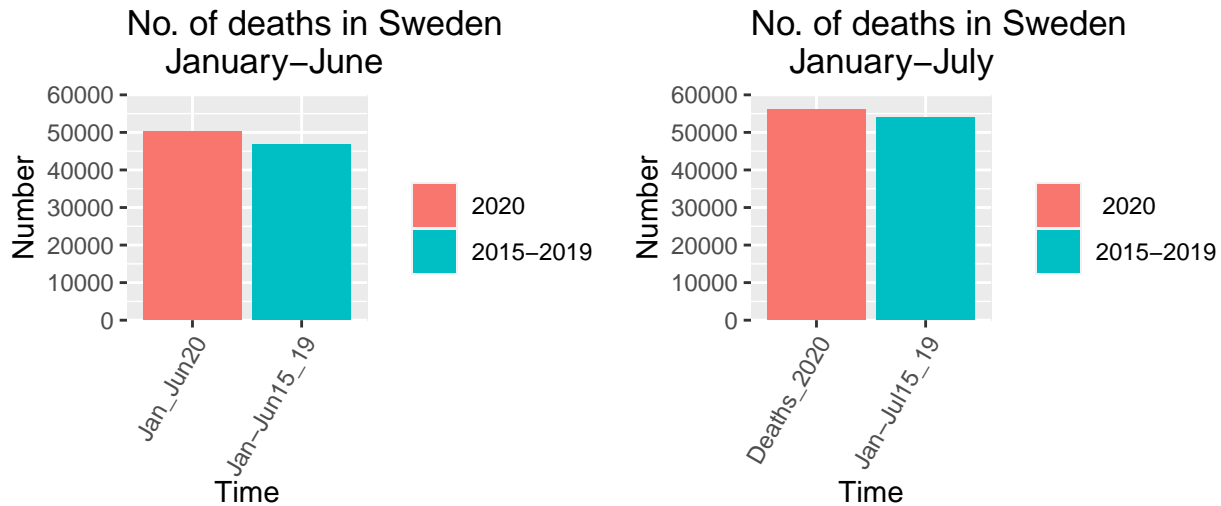
From the plots in Figure 5 we can observe that the excess mortality is slightly higher for the plot showing the number of deaths between January and June than for the plot of January to July. This is a small indication that the mortality is approaching normal levels.

Table 3: Sweden deaths Mars-April

| 2015-2019	2020	Percentage increase
16095	19427	20.70208

From Table 3 we can observe an excess mortality in 2020 compared to previous years, but we can not say, based on this plot and the data from Eurostat, that the excess mortality was 50% as was said in the news report. From this plot we can say that in 2020, the number of deaths have increased by 20.7%.

Covid-19 in Sweden

In this section we are going to delve into the Covid-19 in Sweden and study the difference between counties. Data on the number of Covid-19 cases for each county is published by Folkhälsomyndigheten [10] daily and

the numbers are from up until 13 August 2020. The data used to plot the map of Sweden below is used from the course MT5013 Statistical Data Processing HT18 [13].

Figure 6: Covid−19 cases per 100 000 inhabitant in Sweden per county
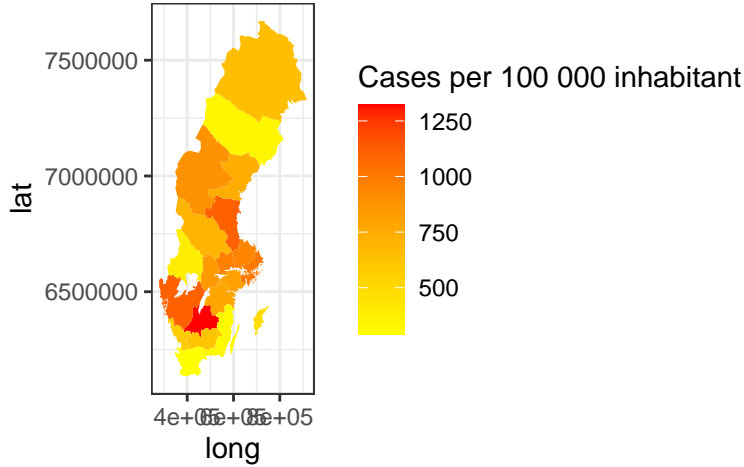
From Figure 6 of Sweden we can observe that the there is one county that has the highest number of cases per 100 000 inhabitant and that is Jönköping. The counties with the lowest cases are found in the south of Sweden; Skåne, Kalmar, Blekinge and in the middle of Sweden the county is Värmland and in the north of Sweden the county with the lowest cases is Västerbotten.

The instantaneous reproduction number R(t) in Sweden

The instantaneous reproduction number R(t) is a reproduction number that varies over time and is defined in Lecture 5 as

$$R(t) = \frac{I(t)}{\int_0^\infty I(t-\tau)w(\tau)d\tau}.$$

This is the ratio of the number of new infections at time t $I(t)$ and the total infectiousness of infected people at time t, where $w(\tau)$ is the distribution for the infections as a function of the time of the infection [1].

The instantaneous reproduction number can also be smoothed by calculating the instantaneous reproduction number above for a number of τ days [1]. The smoothed instantaneous reproduction number is then defined as

$$R_\tau(t_i) = \frac{\sum_{k=i-\tau+1}^i I_k}{\sum_{k=i-\tau+1}^i \sum_{j=0}^n I_{k-j} w_j}$$

These two reproduction numbers are computed in R using the `EpiEstim` package, as was done in Lecture 5. We are going to plot these reproduction numbers for Sweden from the first Covid-19 case in Mars to July 31st using data from Folkhälsomyndigheten [10]. In our calculations we have to include the lag time for the stages of Covid-19 [5]. It takes 7 days for a Covid-19 infected person to have difficulty breathing, it takes 12 days for people with mild Covid-19 to start to improve whilst in the serious cases it gets worse. It takes about 19 days for a seriously infected Covid-19 person to die.

Figure 7: The Instantaneous Reproduction Number R(t) in Sweden
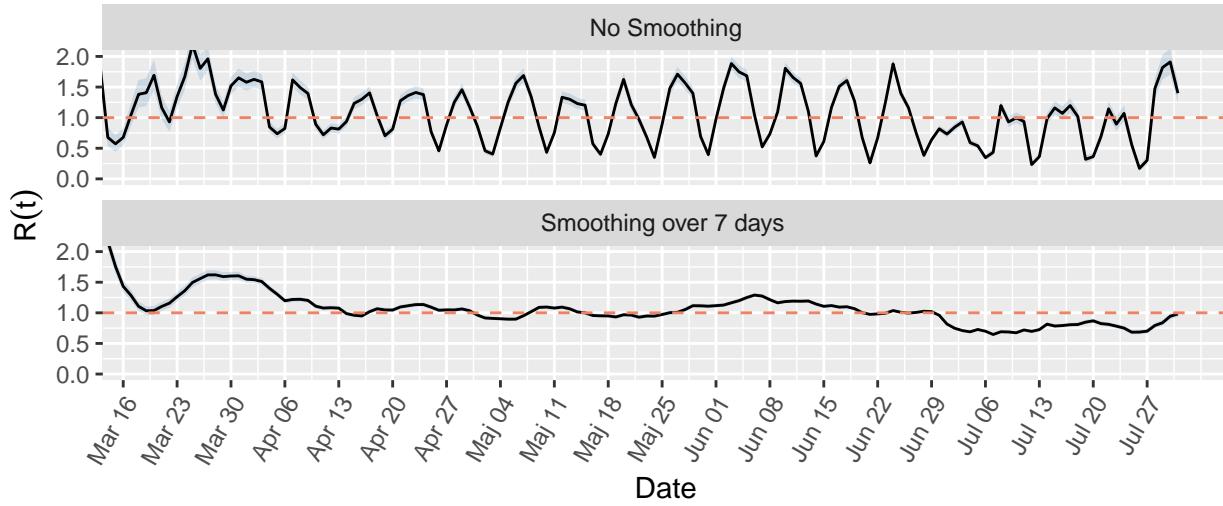
From the first plot in Figure 7 we observe the instantaneous reproduction number from Mars to July and we can see that in the begining of Mars, the number was about 2 and afterwards it has been between 1.5 and 0.5. In the second plot with the smoothed instantaneous reproduction number we can also see that in the beginning the number was over 2 but then it has decreses to about 1 to 0.5. From Table 2 were we calculated R_0 we found that it was 1 for Sweden for the whole period between Mars and July and looking at the plots above we can see that the average reproduction number must be around 1.

Discussion

In this project we have studied different statistics of Covid-19 and mortality in Europe. From the time series of the number of Covid-19 deaths we found that the peak for the majority of countries was in April and that the large increase in the number of deaths occured after lockdown. Here further studies can be made when we know the end dates of the lockdowns for each country to see if the number of Covid-19 deaths will increase. The reproduction number, based on the fraction of infected people and the population, was found to be equal to 1 for some European countries. The proportion of deaths caused by Covid-19 from January to July 2020 were between 0.1% and 14% and the countries with the highest proportions were Sweden, United Kingdom, Spain, Italy and Belgium. There was incomplete data for some of the Eastern European countries so they are not included in the map, but the other Eastern European countries all had very low proportions of Covid-19 deaths. This can be due to underreporting from the government on the actual number of deaths or they have not yet collected all the statistics. From the plots of the mortality in Europe we observed an excess mortality in 2020 for the period January to July compared to the average of the last four years for Belgium, Portugal, Sweden, France, Spain and the United Kingdom. These plots can are likeliy to change later in the year when all the numbers have been collected from all countries. Looking at the excess mortality in Sweden we could observe that the more time that has elapsed the less the excess mortality. Further studies can be made to observe if this pattern holds for more countries in Europe and also further in the year when we have more data. Lastly we studied Covid-19 in Sweden and found that using cases per 100 000 inhabitant in Sweden per count, he number of cases differs quite a lot for each county. This could be due to that there is a difference for each county whether the people who have Covid-19 are tested. We also calculated the instantaneous reproduction number over time from Mars to July and found that the number was first at 2 and then it has been between 1.5 and 0.5.

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