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A Short Introduction to the Corona-crisis and its epidemiologic background

Group 1

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Introduction

This report is part of an academic project at the Frankfurt School of Finance & Management. This is the first half our work on the some problems of the current Corona-crisis. Part A will address the question of how the severity of virus outbreaks is measured and how Corona and the common flu compare in these frameworks. Part B will proceed to discuss how the underlying characteristics of corona contributed to its quick spread all over the world. Lastly, part C will go into further detail on past pandemics and what they taught us.

As we all know, not all sources of information are reliable. This being a report by a course on epistemology, we aim to give the reader reasonable justifications for our sources. While we consider peer-reviewed scientific papers and articles from major international newspapers somewhat safe we will present a short defense for information from other sources when they are first introduced.

In addition to this report we implemented a companion website on which interactive versions of some figures and additional information will be made available. Its current state can be seen at https://ctecorona.herokuapp.com/. The code used to generate most of the figures can be inspected at https://github.com/bernhardkissler/cte_corona_report_.

A) What exactly is the Corona-crisis?

1. How do we measure the severity of a disease?

When comparing influenza to Covid-19, it is important to realize that influenza can take different forms. We need to distinguish between seasonal influenza, which reappears every year peaking roughly between December and February, and pandemic outbreaks. According to conservative estimates, seasonal flu regularly infects between 3% and 11% of the population of the US, which is roughly comparable to European countries. (Tokars, Olsen, & Reed, 2018)

Because seasonal flu is caused by several different strains which mutate quickly, the severity of successive seasons can vary a lot. There are a few frameworks which can be used to evaluate the extent of a virus outbreak. A notable example is the Pandemic Severity Assessment Framework used by the US CDC. (CDC, 2017)

Pandemic outbreaks of influenza are rare, but they can cause many deaths like the Spanish flu in 1918 which will be discussed in detail later on. A more recent example of a flu pandemic was the 2009 outbreak of a novel strain of (swine) flu during which more than 60 million people were infected in the US alone, according to estimates. (Shrestha et al., 2011)

In this first section we will focus on the seasonal flu instead of pandemic outbreaks because most people will have a better understanding of seasonal flu and will be able to compare it to Covid-19. Before we can look at the numbers describing the severity of seasonal influenza, we need to think about how to measure the severity of any pandemic.

As mentioned before, there are several different frameworks to assess the severity of pandemics and epidemics. After the 2009 epidemic, the WHO developed the qualitative Pandemic Influenza Severity Assessment (PISA) framework, recommending an evaluation along three axes. These axes are the transmissibility, seriousness and impact of any outbreak. Transmissibility measures how many people per unit of time are infected, its seriousness depends on the symptoms and distribution of symptoms over all infected, while impact is supposed to measure the effect the outbreak has on the health-care system and the society as a whole. (WHO, 2017)

Because the impact is hard to measure objectively if only qualitative scales are used, the US CDC developed the Pandemic Severity Assessment Framework (PSAF). PSAF is based on only two main factors, the severity and transmissibility of a new disease. These factors can be estimated based on routinely available data.

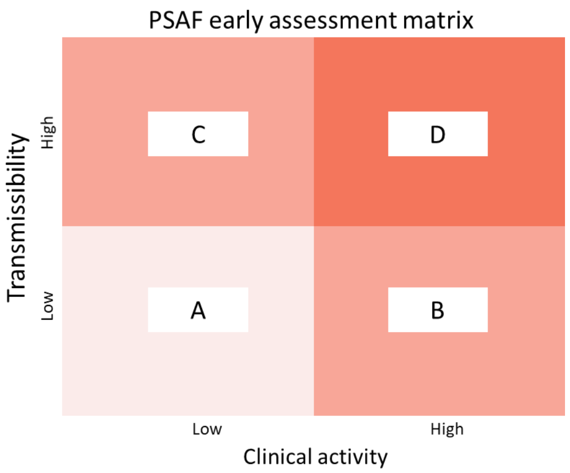


Figure A.1 – PSAF early assessment matrix
This is a schematic representation of how new diseases may be categorized in their early stages according to the Pandemic severity assessment framework by the US CDC. It is based on (Reed et al., 2013).

PSAF has found continued application in the scientific literature. Typical measures of transmissibility are the symptomatic attack rate, R_0 or outpatient visits for the illness. Clinical severity is measured by the Case-fatality ratio, hospitalization rate and deaths in case of hospitalization. Oftentimes not all of these measures are available for all regions where an outbreak is recorded. PSAF's modular nature means that even if some measures are not initially available, we can still use the available data and close proxies to estimate the situation. After it is decided which measures to use for a given pandemic, their values are scaled to be comparable to past outbreaks. This allows for easy comparison between current and past pandemics.

During the early development of an outbreak, PSAF uses the measures described above to classify the outbreak in one of only four quadrants, which makes early assessment possible and helps generate appropriate responses to the outbreak.

Later on, when more data is available the assessment is extended to a more granular scale for both measures. This is shown on the next page and can inform more long-term efforts to manage the disease. High measures of hospitalization with low transmissibility measures could for example lead to a shift of resources from prevention to treatment capabilities. Similarly, high R_0 could mean that experts and politicians need to work to change public perception to reduce social contacts.

Figure A.2 on the next page shows the severity of the current Covid-19 outbreak in comparison to notable epidemics of the past century. It is based on the PSAF framework discussed above and indicates that there are significant differences in the severity of Covid-19 between different age-groups. We adapted this image and added another estimation by a working paper which has not yet been published. Still it is obvious that even with the same framework different people may reach different conclusions. Using different measures and data from different regions and phases of the epidemic may change the outcomes. This is one reason why it is hard to estimate the severity of an epidemic.

We compiled four different estimates of the severity of Covid-19 in Figure A.2. Apart from the initial estimation by Prevent Epidemics, all estimates are made on an aggregate level for all ages. We see very well that all of them imply that Covid-19 is very active clinically for most of the infected. They differ more when it comes to transmissibility. Prevent epidemics and Think Global Health assume moderate to little transmissibility while Matrix global advisory and the academic article by Napimoga, Freitas and Donaliso imply very high transmissibility. This might be because the latter two were conducted a little earlier when most countries had not yet implemented any countermeasures to stop the spread of the disease. All estimates have in common, that they categorize Covid-19 as more transmissible and clinically active than seasonal flu and most of the bigger flu epidemics of the last 100 years. Still only Matrix Global Advisors and Prevent Epidemics imply that Covid-19 might pose a risk to the Spanish flu of 1918. While these estimates provide a robust illustration of the data available so far, they are likely to change in future studies as additional data becomes available.

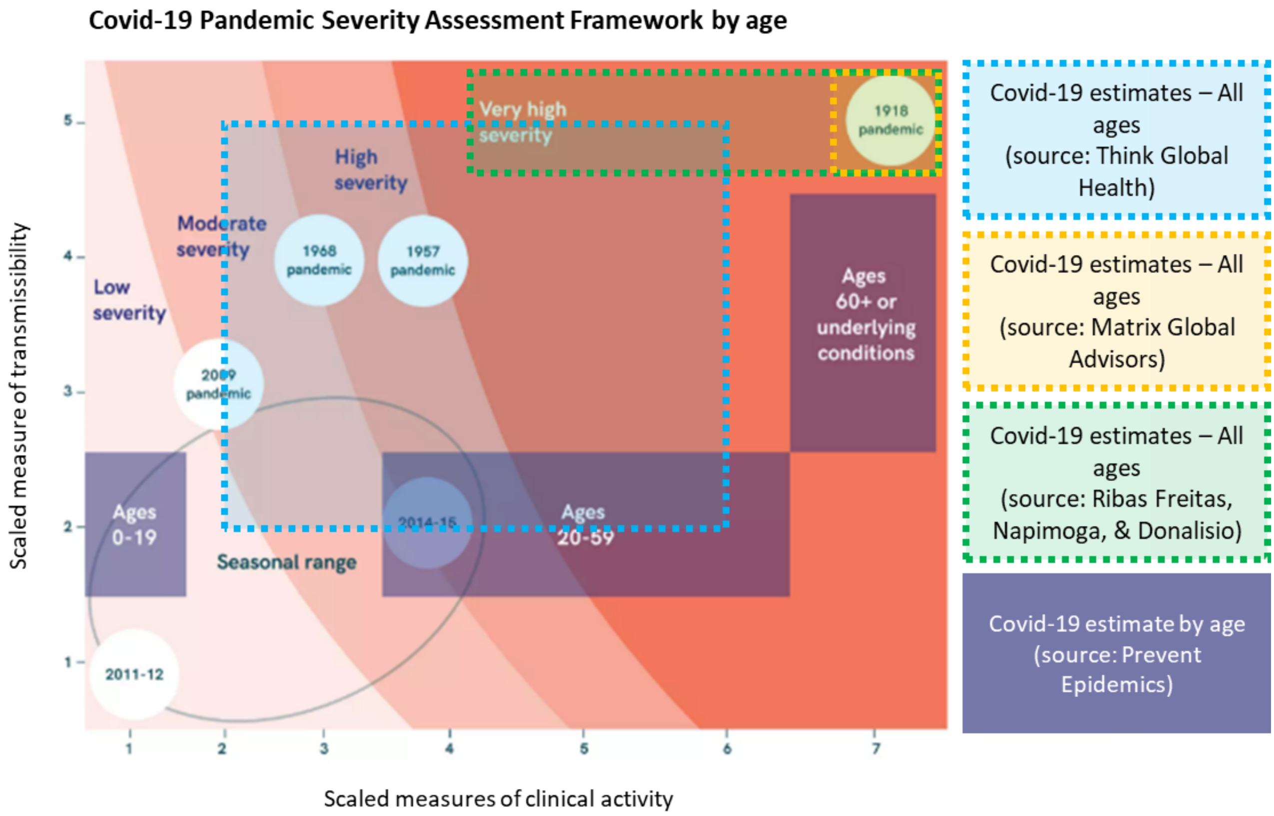


Figure A.2 – PSAF complete assessment matrix
This Graphic is adapted from "Prevent Epidemics". We added three other estimations of the Covid-19 outbreak. The first is from Think Global Health, an initiative of the US Council on foreign relations (Shaphar, McClelland, & Frieden, 2020). Another is an estimate by Matrix Global advisors, a consultancy firm with a focus on public health (Brill & Robinson, 2020) and the last stems from a working paper by Ribas Freitas, Napimoga and Donaliso (Ribas Freitas, Napimoga, & Donalisio, 2020). "Prevent Epidemics", where we got the initial figure, is a program by the "Resolve to Save Lives" initiative. Resolve to Save Lives is headed by a past director of the CDC and is backed by the Bloomberg Philanthropies and Bill & Melinda Gates Foundation among others. It is aimed at providing the public with reliable information on the readiness of countries concerning infectious outbreak ("Insights | Prevent Epidemics," 2020).

2. How does Covid-19 compare?

As we know today the course which Covid-19 can take is highly variable (RKI, 2020). So far three major illness groups have been recognized. We know that *80% (as of 17.04.20)* of the people infected by the Covid-19 Virus are having a mild to moderate course of the disease (RKI, 2020). A mild course of the disease is characterized by the absence of any pneumonia while moderate courses can have slight indications of pneumonia (RKI, 2020). About *14% (as of 17.04.20)* of the infected people are having a hard course of the disease which means they suffer from shortness of breath with a corresponding oxygen saturation below 94% (RKI, 2020). 6% belong to the share of people with a life-threatening course of Covid-19 including symptoms as a collapse of the lung, septic shock or organ failure (RKI, 2020).

The share of people within each severity group is nearly constant across different countries. But what differs significantly is share of fatal cases. While Germany has *8,600* confirmed deaths in *183,294* confirmed cases the US has *105,557* confirmed deaths in *1,816,879* confirmed cases *(as of May 31, 2020)* (JHU, 2020). To achieve a comparable base on which we can measure the fatality of Covid-19 within a nation we may use the "Case Fatality Rate" (CFR). It is expressed by the Number of deaths from the disease divided by the number of diagnosed cases of disease.

But there are two major problems with the CFR that one should be aware of when assessing this number. First of all, the denominator which counts the number of diagnosed cases is heavily dependent on the total number and reliability of tests. As we assume a high number of people infected but not tested this problem will affect the CFR number to be more diluted.

The second problem occurs when observing the confirmed deaths in the numerator and affects the number vice versa. In an ongoing and fast-moving pandemic as the Covid-19 Virus there will be always a time lag in the number of confirmed cases. (Ritchie & Roser, 2020) Some people infected as of now will die later from the disease. As of now we can identify the time between symptom onset and death ranging between two and eight weeks with an average of 23 days. (WHO, 2020) Given this problem the CFR will even underestimate the true mortality of a disease.

Furthermore, there is a more general problem with the deaths which the Covid-19 Virus has caused. It is explicitly defined which role the Covid-19 Virus took in the fate of infected people who died. There is no clear distinction to which extent previous diseases have played a role in the cause of death. (Zhou et al., 2020)

By being aware of these problems with the CFR we can interpret the findings in the chart below. Please note that both axes are not true to scale. The key takeaway from this chart are the dotted grey lines, which indicate the CFR rate.

A more robust measure than the CFR is the infection fatality rate (IFR). Technically it works in the same way as the CFR but for a closed event in a strictly isolated community. So far there are only rare data on such closed events but a recent paper from the university of Bonn determines first insights into cases with a clear IFR. The study came with a result of 7 deaths in 1,956 cases, a corresponding ratio of 0.358%. Even given the fact that this case study has investigated a closed case it is still a projection. (Streeck et al., 2020)

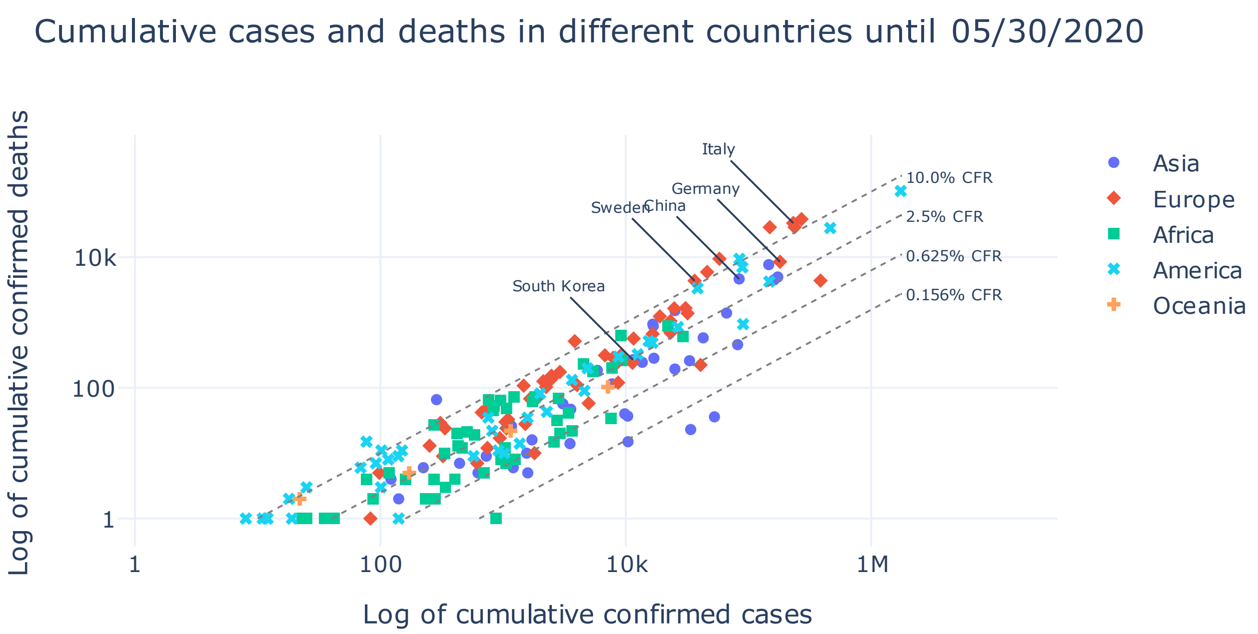


Figure A.3 – Cases of Covid-19 and death rates around the world
This figure shows cumulative cases and deaths from Covid-19 (both on log axes) in different countries. We added lines indicating special case fatality rates. The idea for the chart came from (Ritchie & Roser, 2020) *and the data from the ECDC. An interactive version can be found in the companion website to this report.*

Figure A.3 was generated on May 31, 2020 based on current data from the European Centre for Disease Control and Prevention (ECDC). It shows cumulative deaths due to the Coronavirus in relation to cumulative confirmed cases by country and continent. Both series are arranged on logarithmic scales. We added dotted lines representing case fatality rates of 10%, 2.5% etc. respectively. The code used can be inspected at (Kißler 2020). The idea for this graph came from (Ritchie & Roser, 2020).The main insight is that most countries feature a CFR of 2.5 to 10 percent with a significant number between 0.625 and 2.5 percent. This is comparatively high for a disease as infectious as Covid-19. This holds true for countries with very different proportions of infected populations and there is no easily distinguishable difference between the different continents when it comes to the case fatality rate. Part two of this report will focus on countries and their reaction to the threat, covid-19 poses. They are pointed out on the graph.

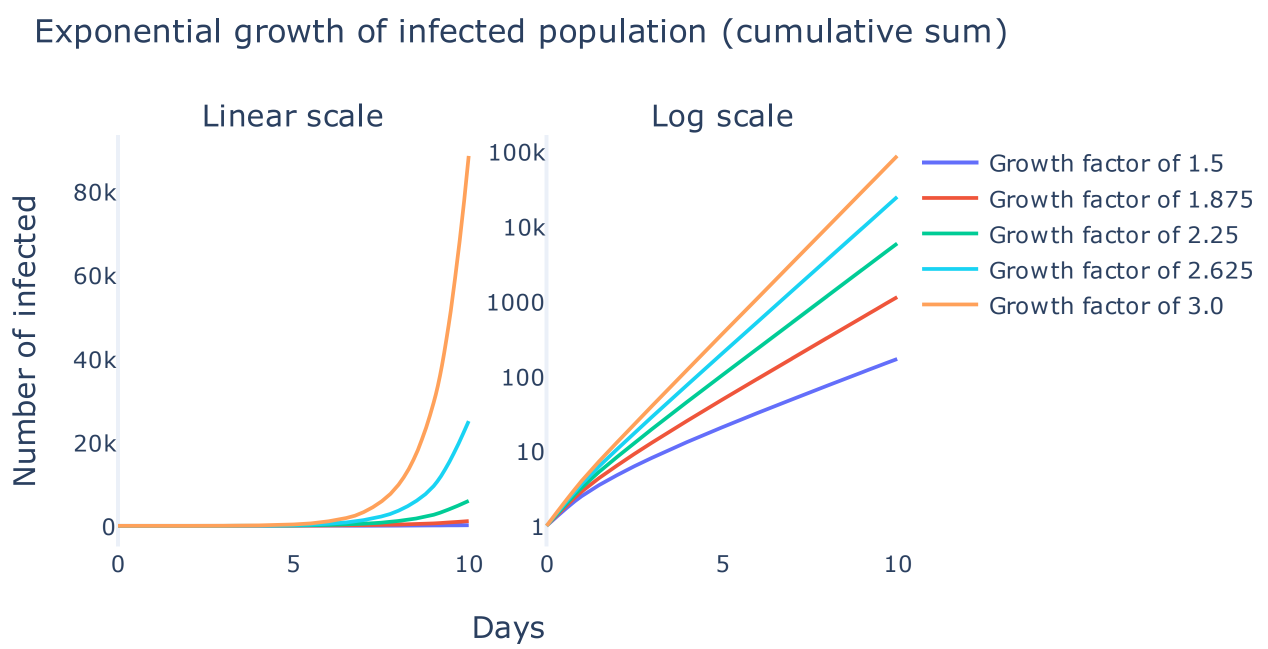


Figure A.4 – Development of infected populations with exponential growth
This figure depicts exponential growth processes of an infected population for similar growth factors. It shows them both on a linear and a logarithmic scale. The code for this figure and an interactive version is available at (Kißler 2020)

Figure A.4 is based on the following function:

$$Number\ of\ Infected(t) = Infected\ In\ t_o * Growthfactor^t + Number\ of\ infected(t_{-1})$$

Given the recent proliferation of logarithmic graphs, we decided that it would be interesting to see the data both on a linear scale and a logarithmic scale. The above example shows the exact same data in both subplots, which once again proves that the way information is displayed matters a lot. Topics like this will be explored further at a later point when the problems of expert communications are discussed.

Apart from the described issue with the axes, the graphs' message is quite clear. It is easy to see that even minor changes in the growth factor which represents the number of people an infected infects per day can lead to big differences in the total number of infected on the tenth day. This measure of growth factor is related to the more widely known R_0 in the following way:

$$R_0 = Growthfactor * Duration\ of\ infectiousness$$

Given this formula, a growth factor of 1.5 with an infectious period of 7 days, we would get a R_0 of 10.5. Similar to Figure A.3, the calculations for this figure are available at (Kißler 2020).

3. Why is it so hard to interpret data about cases confirmed through tests?

Testing is one of our main sources of information about Corona. Ideally, it helps both in determining how big the infected population is and in finding out which patients with which symptoms are connected to the epidemic. This is why it is important to think about its shortcomings as well. This part of our report will try to give an account of these and illustrate them through the use of simple models.

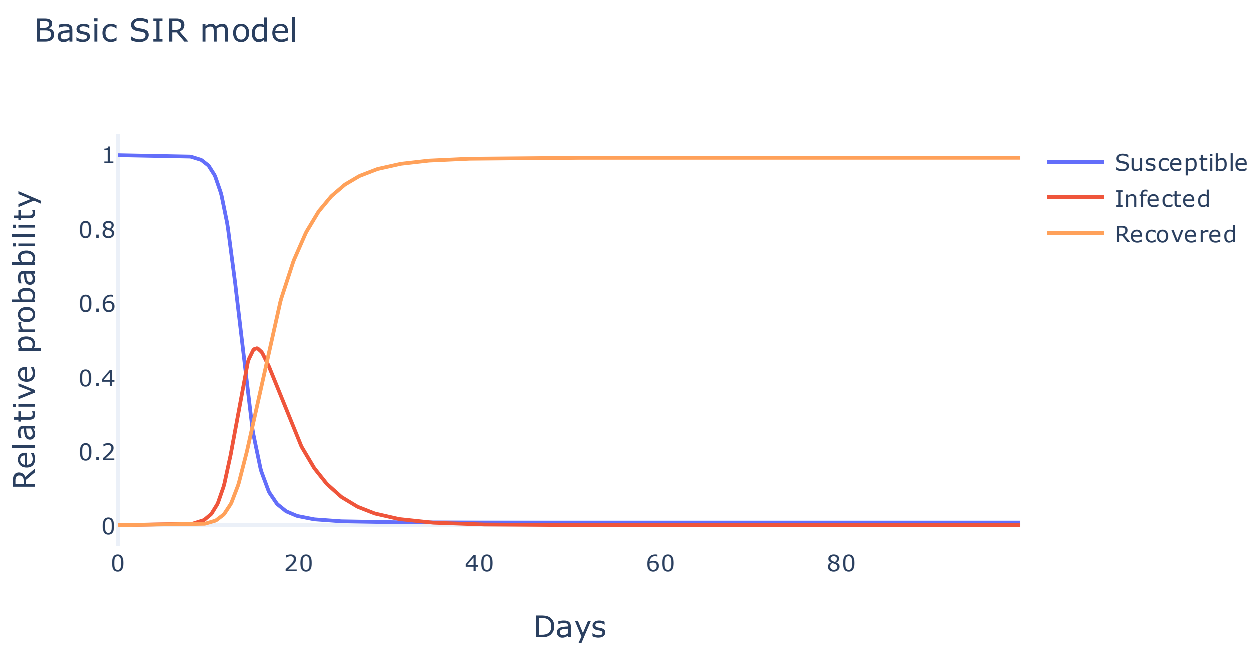


Figure A.5 – SIR a basic compartmental model
This figure shows a basic epidemiological, compartmental model made up of three compartments. These are Susceptible, infected and recovered people. It simulates a period of approximately a quarter of a year and provides the relative probability of the different compartments. The code is available online for inspection.

Above you see one of the easiest epidemiological models which can be used to predict the spread of an infectious disease in a given disease, the SIR model. The SIR model is a compartmental model and the development of its compartments is governed by differential equations and the parameters which the modeler provided. While this might sound difficult at first, it is a very useful tool to think about an epidemic and can be expanded to arbitrarily many compartments.

The above-mentioned compartments are mutually exclusive categories into which every member of the chosen population can be sorted. At the beginning, all except one are susceptible to the disease, as they have not been sick before. The one person who is not susceptible is infectious and starts spreading the disease among his peers. This spreading is modelled by subtracting a small percentage from the susceptible population and adding it to the infectious population. This percentage is bigger the more susceptible and infectious people there are. Naturally, people do not stay infectious forever. Because of this, they have to be removed from the infectious compartment and added to the removed compartment after a few days. A last dynamic that is notable is what happens with the removed population. In this simple implementation of the model they stay removed for ever instead of returning to the susceptible population after some time. This behavior is equivalent to the assumptions that immunity lasts forever after having been infected.

We will add different compartments and measures to analyze different ways of testing for the disease and their implications for our knowledge about it.

When testing for a new sickness, there are two different strategies with fundamentally different aims and outcomes. The first being "reactive" testing. This is often employed during the early development of an outbreak, when few tests are available and medical resources in general are not yet fully mobilized. This approach means that mainly people who present typical symptoms and the people who came in contact with them will be tested. The main information we can gather from it is the “positivity rate”. This rate can be calculated as the ratio of positive tests over all tests. A high positivity rate indicates can have two interpretations. It could either mean that a big part of the overall populations is infected or, more likely it means that testing is not sufficiently randomized to give an accurate indication of actual prevalence of the disease.

While this kind of testing can help prioritize resources to areas with clusters of infection and help in early studies on symptoms, this approach does not allow us to find out which proportion of the total population has been infected. This measure is referred to as the “prevalence” of a disease in a given population. The other strategy is "representative, random" testing. It requires a big number of tests and is therefore usually only available later during the epidemic. The aim of this approach is to test a representative, random sample of the population for the disease. This can be especially helpful in finding clusters of disease where symptoms have not yet shown and learn more about the broader distribution of symptoms, the prevalence mentioned before.

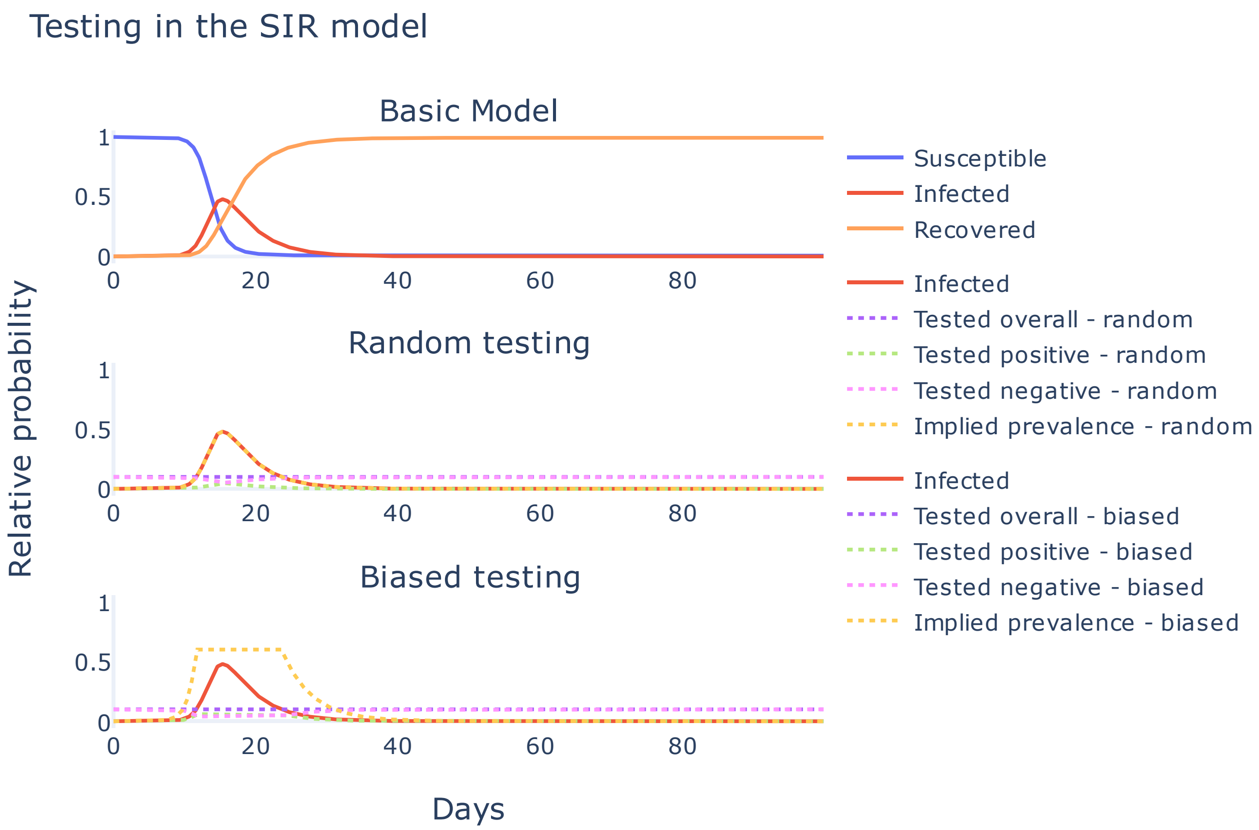


Figure A.6 – An illustration of different testing strategies in a compartmental model
This model includes simple simulations of the insights different testing strategies might provide into the absolute number of infected and the prevalence of the disease in the overall population. The code is available online for inspection.

Figure A.6 is a simplified depiction of random testing in an SIR compartmental model. At this point we used values that improve readability of the figure instead of realism. The model starts with a susceptible population of 1,000,000 people and 1 infected person. We assume a growth rate of 1.25 and an infectious period of 4 days yielding a static R_0 value of 5 over a period of half 100 days. We can see quite clearly that this high value in such a means that everybody has been infected and recovered within less than 40 days.

After this basic interpretation of the figure let us look at testing part of this model. We implemented both a model for random and for biased testing. In both cases we assume that 10% of the population are tested every day in the beginning with growing test rates throughout the outbreak. This is of course unrealistically high, but it makes reading the figures much easier and does not influence the basic insights from these models. We also assumed that tests were perfectly accurate and that they yield results immediately.

Obviously, these assumptions are not realistic. Oftentimes available tests have moderate to high rates of false positive and false negative results. This is especially true in the beginning of an outbreak when tests are still in development. In addition, they often take some time to yield results and there are many administrative problems when trying to test large parts of the population.

Let us first look at the model for random testing. As the composition of the population changes from healthy and susceptible through infected to recovered, the ratio of positive and negative tests changes accordingly. If we now calculate this ratio, the Implied infected percentage of the population, we see that our implied measure tracks the actual prevalence of the disease in our population accurately. Meanwhile, the number of positively tested people is mostly much smaller than the number of actually infected people, which means that their number is not a good proxy for the latter.

Now to the biased testing model. We calculated the same metrics as before, but this time we assumed that people who are sick are more likely to be tested. Reasons for this could be that they already show symptoms or that it is known, that they came into contact with somebody who tested positive. To model this, we calculated negative tests as the minimum of available tests and infected people multiplied times 0.6. Taking the minimum of available tests and infected people means that we have less infected than available tests, the number of negatively tested is lower than that of infected people. At the same time, we know that we cannot test more people negatively than we have available tests. This is equally expressed in the use of this minimum. We chose to multiply this minimum with 0.6 because we assume that we will never catch all infected and this buffer variable allows us to catch this inefficiency in tracing contacts and finding asymptomatic, infected people.

Interpreting this model is straight forward. We see that the number of infected and of those who tested positive are very similar in the beginning of the outbreak. This changes when the number of infected approaches the number of available tests because of the constraint this poses. This is even more so as our buffer variable constrains the proportion of positively tested to 60% of available tests. After some time, the number of infected is therefor much higher than those who tested positive which is similar to the random testing strategy. What is very different is that the implied prevalence is much higher than the actually infected population. This was to be expected, because we stated that infected people are more likely to be tested in this model than susceptible or recovered people. This means we can no longer use the implied prevalence as a proxy for the overall number of infected people.

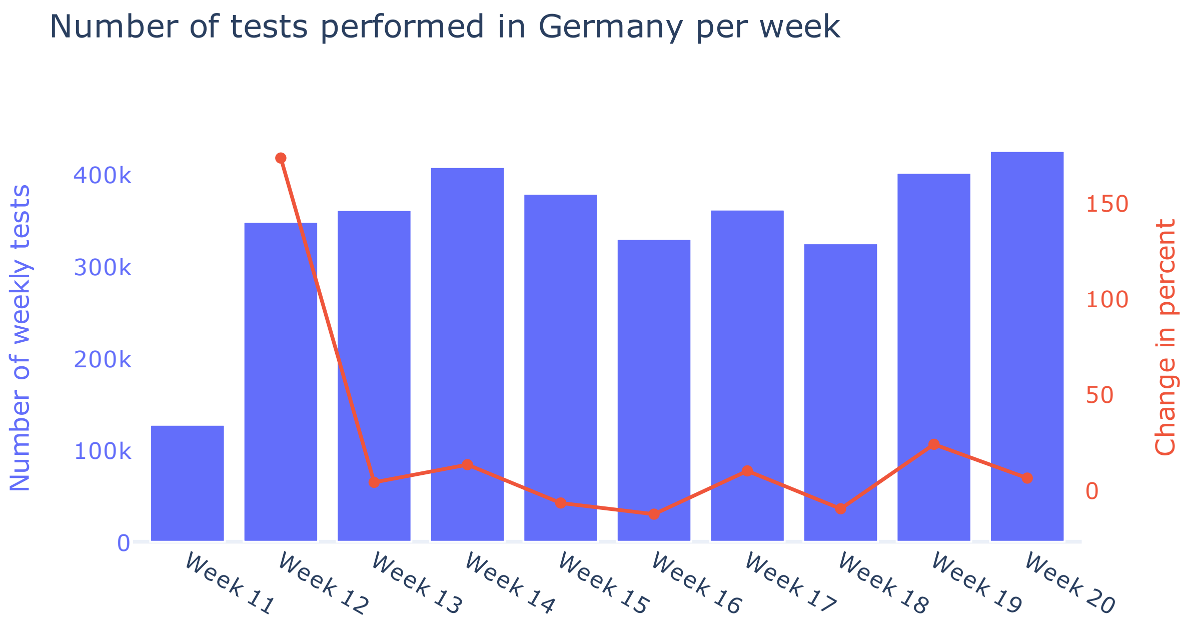


Figure A.7 – Weekly tests performed in Germany
This figure shows the number of tests for Covid-19 performed in Germany per week from March until May 2020. The numbers are based on the reporting of the Rudolf Koch Institute (RKI)(Statista, 2020b).

One last point which becomes apparent in this model is that the number of available tests and its growth is very important for the interpretation of changes in the daily statistics. This is because there are two ways for the number of positively tested people to rise. Either the proportion of infected in the overall population rises or the number of tests rises. As can be seen in Figure A.7. The number of available tests can change dramatically from week to week. This means that when we interpret the number of people who tested positive from week to week, we need to account for this change in the number of available tests to (possibly by dividing the new number by the change in tests) get a more accurate picture of the change.

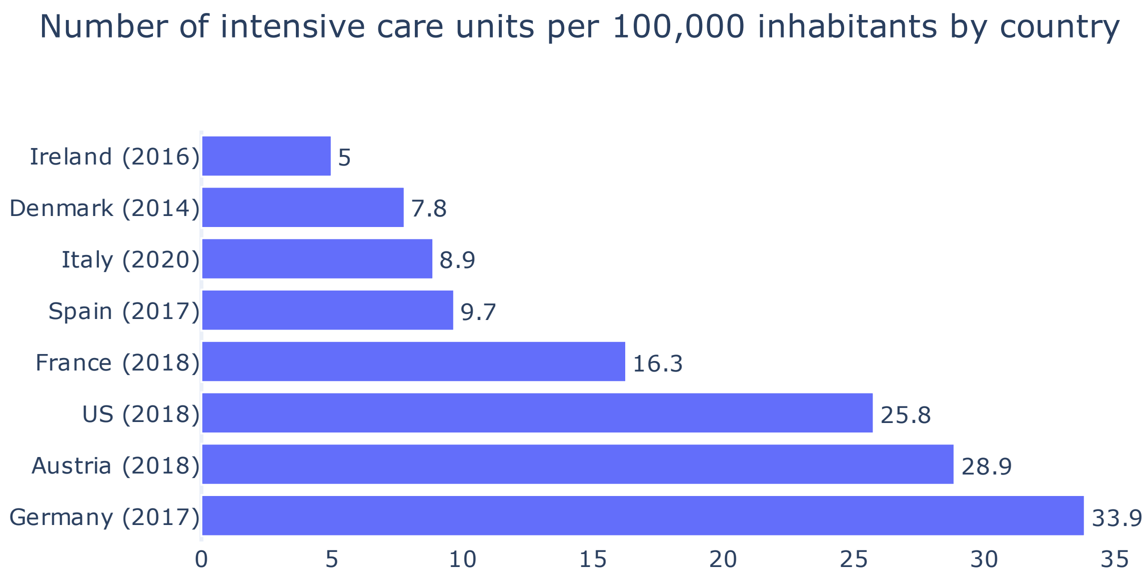
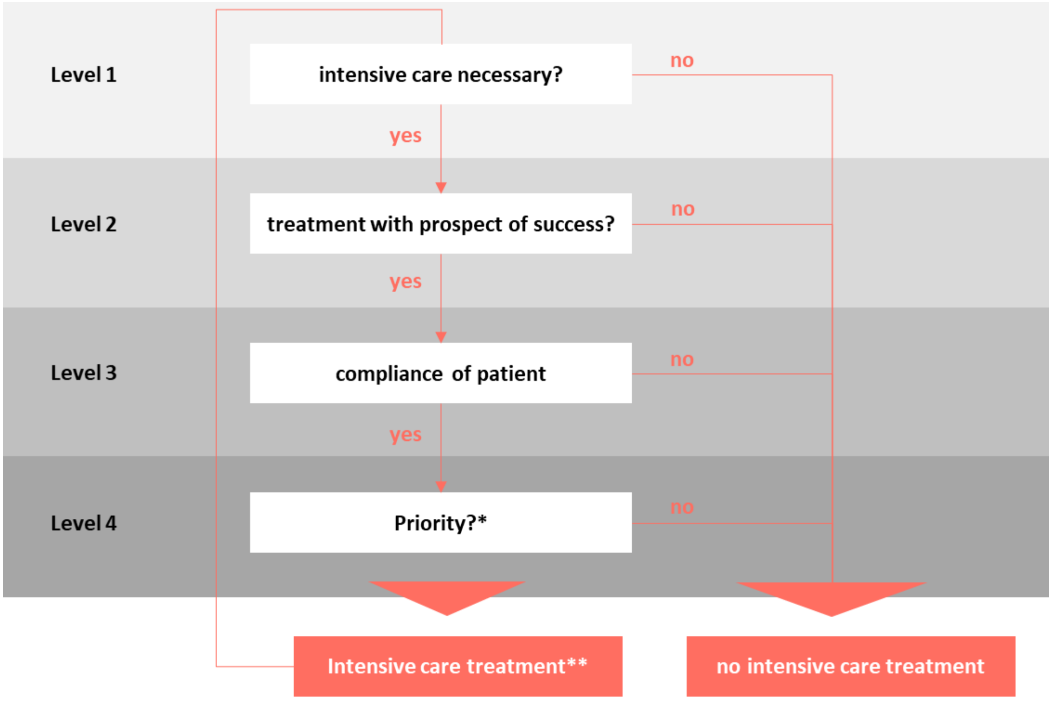


Figure A.8 – ICUs per 100,000 inhabitants
Figure A.8 depicts the number of available ICUs per 100,000 inhabitants in different countries. Because there is no centralized reporting of this data, we indicated in the brackets when this data was published in which country (Statista, 2020a).

In the Covid-19 pandemic we have seen tragic pictures of ambulances lining up in front of hospitals to bring the dead bodies of Covid-19 victims into crematories. Those pictures occurred due to the fact the demand of intense medical care exceeded the capacities in the hospitals. In Italy due to the immense speed with which the virus spreads, doctors were facing the decision which patient to treat and which to let die only a few weeks after patient zero. Such triage situations are known from a state of war in which the military surgeon makes decisions to let a soldier die to treat another. In Italy and France, the order of priority was determined by age. People above a certain age were categorically excluded from intensive medical care to have capacity for younger patients. These cases were especially dramatic since the families often had no chance to farewell their loved ones and if they had the chance it was very limited in time.

If we look at the situation in Germany, the important institutions distinguish between two types of triage situations. First the ex-ante-competition in which the demand for ventilation devices is larger than the supply of unused capacity. Second, the ex-post-competition in which all ventilation devices are in use and a new patient in need arrives. (German Ethics Council, 2020) The crucial point is that while in ex-ante-competition people seeking for help are not medicated and therefore not saved. An ex-post-competition is morally more problematic since a patient is actively killed to save another. In both situations it is crucial to follow objective predefined guidelines to not discriminate against anybody.

Until now there were no situations of ex-post-competition in Germany. Anyway, for the case that the Germany is facing such a situation the process which the affected hospitals have to follow is described in the Figure A.9.



* Prioritization is subject to severity of disease as well as general medical condition of the patient. If a patient suffer from comorbidities he is not in title for intensive treatment.
** The process is subject to constant revaluation.

Figure A.9 – Decision tree - who receives intensive care treatment in Germany
This figure shows the process defined by the German institution for intensive and emergency medical science which to follow to decide who is legitimate to receive intensive treatment once all clinical capacities are occupied.

Figure A.9 shows the triage process in Germany as proposed by the Deutsche Gesellschaft für Intensivmedizin und Notfallmedizin (German institution for intensive and emergency medical care). This decision tree was developed partly based on recommendations of the Deutscher Ethikrat (German ethical committee). In comparison In France those decisions are decentralized. Here every of France 13 regions decide about how to handle the situation if hospital capacities are exhausted. In France the national etic committee (Comité Consultatif National D'Ethique) plays a consulting role when it comes to those decisions as well. In Italy one of the countries hit hardest by Covid-19 a similar, decentralized approach is followed with consulting by the ethical committee of Siiarti.

After discussing the problem of triage on this abstract level, we will now provide a simple model of triage. Like before, we will use a compartmental model to illustrate when these problems might appear.

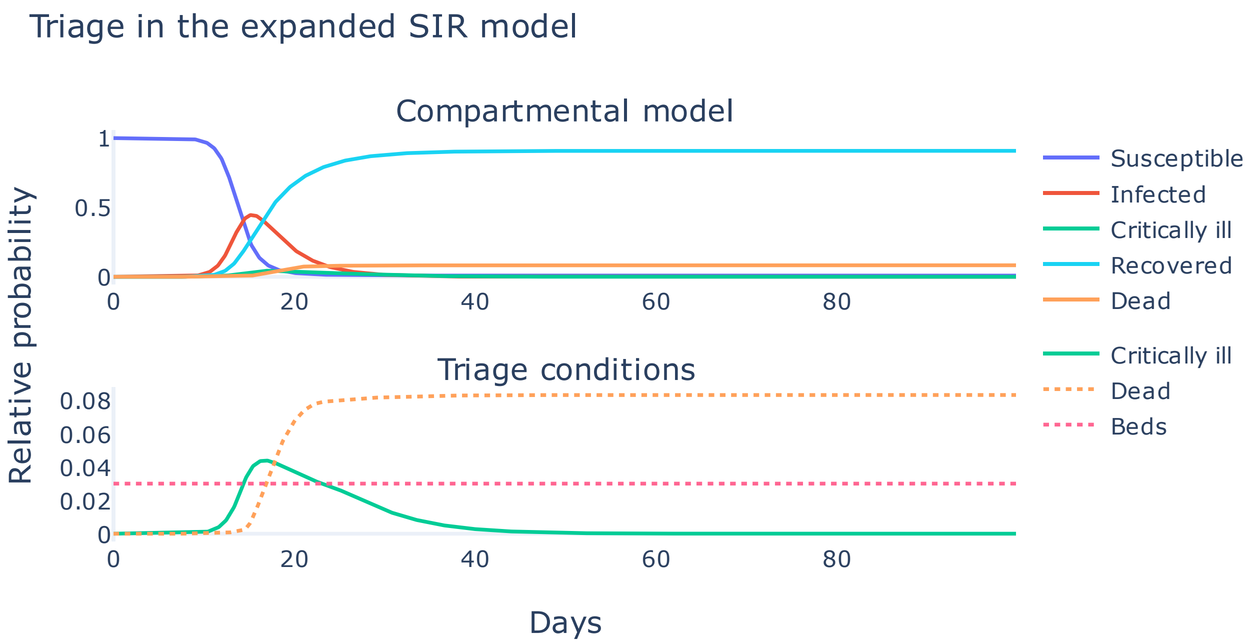


Figure A.10 – Triage in the expanded SIR model
This figure expands the SIR model from before by two compartments and provides a simplified simulation of the mechanisms behind triage. The most important factors for this are death rates for the critically ill which depend on the availability of ICUs (Beds) steeply. The code is available online for inspection

Figure A.10 is an extended implementation of a compartmental, epidemiological model. Its basic characteristics are the same as before, but it includes some additional categories (compartments) into which the population is sorted. Like before, we have susceptible, Infectious and removed people. We added a compartment of critical cases which means that a certain percentage of infectious/infected people will suffer a critical disease which needs intensive treatment. Otherwise their chances of death are very high. To capture this death rate, we introduced a compartment for the dead. A very small percentage of "normally" infected die and all critical cases die if they do not get intensive treatment. This intensive treatment is modelled as the availability of intensive care units per 1000 people. We assume that there are 30 beds per 1000. This is as we have seen in Figure A.7 unrealistically high. We keep it that high for better readability. This means we can now model triage situations in a compartmental model. In this model 2% of normal cases are assumed to die within 9 days of their infection. We assume that 10% of critical cases die within 7 days of their infection regardless of their treatment. All critical cases who do not receive intensive treatment die within one day. We assume that 0.0001% of the population are sick in the beginning. It also displays the number of available intensive care units (Beds), critical cases and cumulative deaths for the SIR model in Figure A.9. All parameters were kept the same.

In the beginning, we see that the number of deaths is slowly rising. As soon as the number of critical cases becomes higher than the number of available beds, they rise dramatically. We see that the number of critical cases starts to drop quickly, because all those who do not get intensive treatment die immediately. This goes on until the number of critical cases drops below the number of available beds again. From then on, the number of deaths rises only slowly until it approaches a maximal value of about 55 million around day 65. We can see in Figure A.9 that the number of infected reaches zero around that time.

B) How to detect a pandemic?

1. Is it difficult to predict a pandemic?

We have known for some time that we might have to face a global pandemic for some time. The forecast of this is based on the fact that a wide range of pathogens exist, which can easily spread to different cities, countries, and continents on international flights. Due to this knowledge, several international organizations such as the Bill and Melinda Gates Foundation and the World Health Organization have prepared in order to counteract pathogens by supporting developing countries in medical care and vaccinations. However, what causes a more demanding challenge is to recognize that these pathogens could impend at an early stage. To predict the particular time for an outbreak is very difficult as well as to answer the question which preparations could have been done before. On the one hand, it seems to be the case that some cautious preparations can be made before an occurrence of a pandemic, for instance the provision of medical protective clothing in clinics. On the other hand, for some pandemics it seems to be very difficult to prepare reasonably, specifically if a great number of special medical devices is required to treat a multitude of people. These specific medical devices could be for instance dialysis machines which are limited in their number.

New Detection Method - Artificial Intelligence and Data Science

The Canadian start-up BlueDot has demonstrated that artificial intelligence (AI) and data science can be used as a new method to detect viruses (Marr, 2020). By analysing studies, news, reports, social media and governmental documents, AI is capable to detect infectious diseases, to quantify the risk of exposure to these diseases as well as to anticipate the impact of it (BlueDot, n.d.). Specifically, BlueDot has been able to spot a certain cluster of 'unusual pneumonia cases' around Wuhan (China) with the help of AI before the World Health Organization or the Centre for Disease Control and Prevention have made warnings public (Stieg, 2020). This not only shows that developed technologies such as AI are capable to track, locate and conceptualize dispersion of infectious diseases at an early stage but also the great potential for the future to be prepared for other possible diseases.

The idea for BlueDot has developed during the severe SARS outbreak in 2003. During this time BlueDot's founder Dr. Kamran Khan, an experienced epidemiologist and physician who has already treated Canadian patients during the severe SARS outbreak, has recognized the necessity to 'spread knowledge faster than the diseases spread themselves' (Stieg, 2020). Moreover, he has learned that "if we rely on government agencies to report information about infectious disease activity, we may not always get that in the timeliest way or as quickly as we would like' (Stieg, 2020). Therefore, the founder is convinced that the internet is an interesting platform to gather extensive data sets helping to detect infectious diseases (Stieg, 2020).

Diving deeper into the case of Covid-19, BlueDot has not only been able to send a public warning but also to correctly identify the locations which are connected to Wuhan. By analysing global airline ticketing data, BlueDot has been able to anticipate the travelling routes of infected people at an early stage and it turns out to be a successful forecast since Bangkok, Hong Kong, Tokyo, Taipei, Phuket, Seoul, and Singapore belong to the cities which have dealt with Covid-19 first (Stieg, 2020).

2. When was Corona and the danger it poses first discovered?

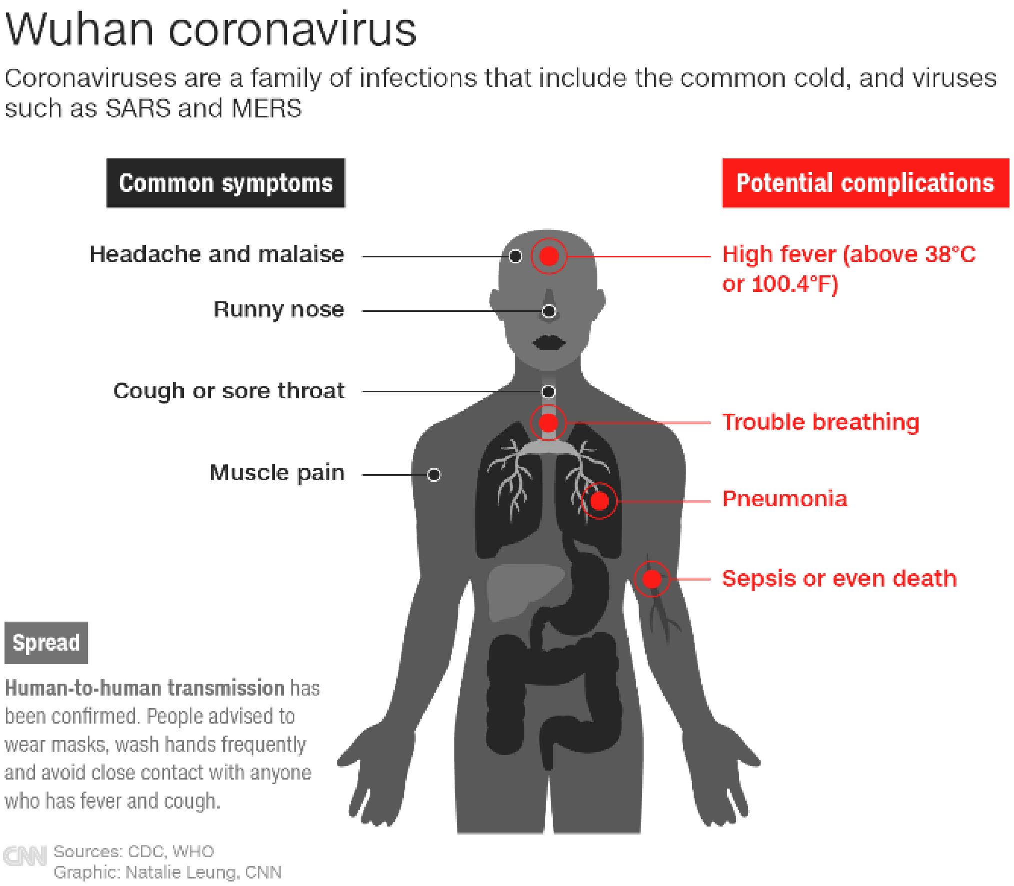


Figure B.1 - Symptoms of the Coronavirus
Figure B.1 shows the common symptoms of the Coronavirus including headache, runny nose, cough, sore throat and muscle pain. Moreover, the potential complications of the Coronavirus are also visualized (Berlinger, George, Griffiths, & Guy, 2020).

The outbreak of the Coronavirus also known as Covid-19 might have started in a Chinese seafood and poultry market in Wuhan, the capital city of Hubei province in central China in mid-December 2019 (Taylor, 2020). So far, the transmission from animal to human on the Wuhan marketplace has been the most prominent view of how the Coronavirus has spread around the world (Taylor, 2020). Considering the beginnings of this outbreak, the Chinese government confirmed increasing cases of pneumonia with unknown cause on 31 December 2019 which have been treated by health authorities (Taylor, 2020) . However, at this point in time, there had not been any evidence for inter human spread of the virus. Based on that, health authorities assured they monitored the situations to prevent the outbreak. At a later point in time, on 11 January 2020, China confirmed its first death which has been caused by the newly developed virus. This has demonstrated the dangerousness of the virus which can lead to severe consequences despite harmless symptoms like a common cold (Berlinger et al., 2020) .

In addition to the prominent view among experts that the source for the Coronavirus was a wild animal in a poultry market in Wuhan, there are different theories about the outbreak. One especially interesting theory is Covid-19 might have had its origin in a laboratory which is linked to China's biowarfare program from where it was accidently released (Gertz, 2020). While some scientists believe, that there is no clear evidence for the poultry market for being the source for the Coronavirus (Manson, Yu, & Cookson, 2020), the scientist Trevor Bredford claims there is no evidence that Covid-19 might have been genetically engineered (Cookson, 2020). Therefore, the lack of certainty about the origin of Covid-19 becomes apparent. As a consequence, the US is now pressing China to reveal more data about the beginnings of the Coronavirus, especially about the time frame before December 31st, 2019 due to the lack of transparency from the Chinese government (Manson et al., 2020). Additionally the WHO decided to begin an investigation into the origin of Covid.19 (Manson et al., 2020).

3. Why is it difficult to recognize the dangerousness of a virus?

In order to gain a better understanding of the difficulty of recognizing a virus, it is crucial to dive deeper into the term pneumonia and its different causes. Specifically, pneumonia is an inflammation of the tissue of lungs that is frequently caused by bacteria namely '*Streptococcus pneumoniae*' (NHS, 2019). However, pneumonia can be caused by many different reasons such as harmful chemicals, smoke, fungi, bacteria, parasites and viruses which only demonstrate a small number of infectious agents (NHS, 2019). Therefore, it is of high difficulty to find out which pathogens cause pneumonia.

Moreover, diagnosing pneumonia is a challenging task since it exhibits symptoms which are similar to other conditions e.g. common cold, asthma, bronchitis (NHS, 2019). Nevertheless, pneumonia caused by bacteria can usually be treated with oral antibiotics (WHO, 2019). Additionally, pneumonia caused by a virus is commonly resolved on its own within a few weeks (Sampson, Johnson, & Wells, 2017). Thus, pneumonia is generally viewed as a harmless illness which occasionally appears in human beings' daily life that can be easily resolved. However, severe cases of viral pneumonia can be life-threatening and require different kind of treatments. It is known that viruses such as chickenpox (*Varicella zoster virus*) and flu (*Influenza viruses*) can lead to viral pneumonia (Sampson et al., 2017).

Severe Cases of Viral Pneumonia

If one has recognized that pneumonia has been caused by a virus, then it is already an insightful finding. However, the path towards this finding is not apparent since one has to test a variety of pneumonia causes in order find the actual cause. Despite the current knowledge of different pneumonia causes, it is of high importance to recognize that the new Coronavirus is not a common type of virus that can be treated with trivial treatments such as antibiotics and antivirals. In fact, no medication has turned out to be effective yet. Covid-19 is a new type of virus which shows a different course than previous outbreaks of viruses e.g. SARS or Influenza. Therefore, a lot of uncertainty exists about the new virus. Moreover, the symptoms of the severe case of pneumonia, the Coronavirus shows that similarity to a common cold e.g. cough, sore throat, runny nose, headache and fever exists. Due to the similarity to a common cold it is difficult to detect the dangerousness of the Coronavirus. Until now, there has been speculation about different variations of the Coronavirus, possibility of a more aggressive course of a virus which evokes severe symptoms (Friebe, Jahrberg, Danner, Bach, & Cremer, 2020).

High Transmissibility

Moreover, the high transmissibility of the newly discovered Coronavirus demonstrates the difficulty of keeping up with the most updated information about Covid-19. As discussed in the question complex A, it is observable that the infection rate is volatile and uncertain. Every day, factors like R_0 changes due to people's behavior in the course of political decisions. R_0 can for example change based on the contact rate meaning the number of people which one meats during the day and a multitude of other complex inputs. Therefore, recognizing the dangerousness of a virus is a challenging task. So far, several Coronavirus studies have been published and there has been some evidence for a high transmissibility of Covid-19 at the beginning of this outbreak. Even though some basic facts seem sure, these studies still varied in their conclusions a lot. For instance, a transmission from an animal to a human as well the possibility for a human to human transmission had not been clearly proven for a long time. Thus, it is difficult to gather reliable information since all facts are uncertain at an early stage of a pandemic and need to be investigated all the time. The path towards a reliable finding is, therefore, a demanding challenge.

Characteristics of a Virus

Generally, it is difficult to detect the dangerousness of a virus since the characteristics of a virus show that not every virus infects human beings and not every virus that has infected human beings leads to illness due to the combat system of our immune system (BzgA, n.d.). However, some viruses cause severe illness such as Covid-19. Since this virus is of a new type which has to be investigated in detail, there is no effective medication yet. Therefore, it is a challenging task to recognize harmful cases of severe viral pneumonia as well as to find suitable medications for specific types of viruses.

Underestimation

Another point worth mentioning is the underestimation of the virus' dangerousness. Specifically, the symptoms of the Coronavirus are without confirmatory testing, easily mistaken for another 'harmless' illness which can be easily treated with medications (Davidson, 2020). Since it is difficult to recognize the dangerousness of the Coronavirus, this may lead to an underestimation of the virus' dangerousness. Thinking about the initial response of the Chinese government reveals that they have not been willing to acknowledge the dangerousness of the Coronavirus despite the warnings of doctor Li Wenliang who is considered to be one of the first doctors to have recognized the dangerousness of Covid-19 (Xiong, Atay Alam, & Gan, 2020). However, the Chinese government has downplayed the outbreak of the Coronavirus. Not only does it point out the underestimation of this virus but also emphasizes the link between epidemics and politics. Governments after all often try to avoid admitting mistakes in the handling of critical situations (Davidson, 2020).

Despite the spread of the Coronavirus in China and the increasing number of deaths in this area, the rest of the world underestimated the situation in Wuhan as well and has not recognized the potential danger of the spread of Covid-19 to Europe at the beginning of 2020. Celebrations such as 'Karneval' in Germany took place and restrictions were not imposed until the mid of March in Germany. Despite the severe situation in Wuhan, there has been a lack of understanding for the Coronavirus and its potential spread to other countries. Names such as 'Wuhan-virus' or 'China-virus' illustrate that the virus has been primarily associated with China at the beginning of the Coronavirus outbreak.

4. What problems do people who try to communicate those dangers face?

What problems are faced by those who recognize danger when they want to communicate danger to others (politicians, the public)? – danger and insecurity communication

The fight against Covid-19, is at least partly a fight against an unknown opponent. There is no question about that doctors and various experts in the fields of virology and epidemiology have been able to accumulate enormous knowledge on the basis of existing viruses and past epidemics. This knowledge gained from experience was the basis for the rapid implementation of initial control and containment strategies, which ultimately saved us from getting completely out of control of the situation, regardless of specific knowledge about the Covid-19 virus. Nevertheless, the unfamiliarity of the virus type Covid-19 poses particular challenges. Every day we are faced with decisions, which are completely new to everyone, but still have to be made. That these decisions in the end would have to be made by politicians is beyond question, it is much more the decision-making process and the dissemination of information in society that is currently somewhat different. Journalists, Physicians, virologists, epidemiologists and other experts are currently moving into the limelight alongside politicians. As attending physicians and experts on viruses and epidemics/ pandemics, they are expected to advise politicians on their decisions on measures to combat the Covid-19 pandemic, while journalists are supposed to inform the general public about current developments in a completely distant and highly complex field of expertise. The uncertainties and constantly changing views on many Covid-19 specific issues complicate the task of the experts and make it almost impossible to adopt a uniform position on the necessary measures. But if experts are not sure what is best to do now, who is? It is precisely this combination of being both the best informed and still not having the full picture that presents the experts with one of their great challenges of how and what best to communicate to politicians and the public.

Physicians, the ones who first identified the virus

Assuming that the virus was formed and spread naturally, doctors in the province of Hubei, China, were the first experts to be confronted with the novel virus. The previous paragraph has dealt more closely with the difficulty of identifying the novelty of the virus. As soon as they have discovered that something and what exactly was different about the symptoms of an increasing number of patients they treated, the next challenge arose. How to communicate these findings. This challenge turned out to be a particularly big one for doctors bound to the outbreak in China. The freedom of opinion and freedom of the press in China is severely restricted by the state and makes it almost impossible for people, and thus also for doctors, to disseminate unfiltered information freely. If such unwanted behaviour does occur, it is not unusual to punish it publicly with severe punitive measures and thus to nip public support in the bud as quickly as possible. (Shi-Kupfer, 2016) The extent to which these restrictions influenced the communication among doctors and their early warnings to the public during the outbreak of the epidemic in China is well illustrated by the example of the Chinese doctor Li Wenliang.

Doctor Li Wenliang was one of the practicing doctors at Wuhan Hospital who had already dealt with the first corona patients in December. Seven of his patients showed symptoms that Dr. Li quickly associated with the SARS virus. On December 30, Li sent a message informing his colleagues about the observations he had made. At that time, he assumed that there was only an outbreak of the SARS virus in the old-known form and waited for his colleagues to take appropriate precautions to protect themselves from infection. A few days later Dr. Li was summoned to the police station where he was asked to sign a document accusing him of spreading false statements and seriously disturbing the social order. He was also threatened that he would be held accountable if he continued his illegal activities. Doctor Li was one of eight people visited by the police in connection with alleged false statements in connection with a virus outbreak. All doubts were nipped in the bud and no precautions were taken for medical personnel. Just one week after Doctor Li's visit to the police, he treated a woman with an eye disease he did not know was also infected with the Corona virus. A few days later, Doctor Li had to be treated in hospital due to severe corona symptoms. It was not until 20 January that the outbreak of a virus was publicly confirmed and the situation in Hubei, Wuhan was classified as an emergency. Doctor Li died on the first of March as a result of the corona virus. His story shows how much earlier the virus could have been contained at the site of the outbreak if the authorities had taken the doctors' early warning seriously.(Hegarty, 2020)

Experts, in charge of the mood in society

One aspect that currently makes the task of experts more difficult is that experts play an important role in confidence and mood in society. People feel powerless in dealing with the virus and are completely dependent on the expertise of others. Since it is obvious that this expertise does not lie with politicians or economic experts as is usually the case, this role falls largely to scientists. In a situation like the one we are currently experiencing, the mood in society is on a knife edge and can tip over within a wink of an eye. When it comes to their own health or the health of those close to them, people are very emotional and quickly get involved with negative mood makers. For this reason, it is all the more important for experts to deal sensitively with the trust gained. However, the questions arise what experts do we require and how exactly should they fulfill their tasks? (Stevis-Gridneff, 2020)

Currently it appears in the media that the most prominent experts in the fight against the Coronavirus are mainly virologists. Obviously, they play a very important role at the moment and are the key to learn to understand our enemy in the first step and hopefully to be able to treat the virus in the future. The main focus in the field of virology is the characterization and classification of viruses, the study of their properties and reproduction, as well as the prevention and treatment of viral disease. (Murphy, 2019) Using the corona virus as an example, virologists first classified the novel virus. One example is the classification of Covid-19 virus as a form of the SARS virus. The virus was then assigned properties such as attacking the lung or survivability of the virus on different surfaces. Virologists are currently working on the prevention and treatment of the virus in the context of numerous projects to develop a vaccine and drugs to cure infected patients. However, between the research and the treatment or prevention of the virus, further knowledge is required beyond the expertise of the virologists. Epidemiologists and pandemiologists are particularly concerned with the spread and consequences of health-related conditions and events in the population. They thus provide important supplementary knowledge for decisions on effective measures to contain the virus. (Rothmann, 2002) An example of this is the observation of epidemiologists/pandemiologists that the virus mainly spreads when several people are together at a close distance, who in turn live in the same area, from which the so-called Custer spread results. This observation in turn led to the conclusion that in such severely affected regions, more severe measures are required than in other less affected areas. The more precisely we get to know the virus, the more experts can help us, who seemingly have nothing to do with the fields of virology, epidemic or pandemic.

Let us imagine the following: In the course of the gradual re-opening of shops and restaurants, the question currently being asked is exactly how best to do this. The aim is to install the best possible measures to enable people to go about their daily lives as far as possible, to get the economy going again, to give them a feeling of security and at the same time keep numbers of infection at a rate at which our medical capacities are not risked of being exhausted. It is important to note that we in Germany are currently in a situation where we should keep an eye on several goals at the same time. The following illustrates why this fact is crucial. Before the lockdown a few weeks ago, the focus was clearly on minimizing the number of infections in order not to lose control of the spread of the virus and at the same time to increase medical capacity. If the priority is to minimize infection rates, contacts must be minimized. So, the successful measure of a lockdown was quite clear at that time. Fortunately, in Germany we were able to put the period of necessity of such strict measures behind us relatively quickly and now have to define new objectives. Examples of this could be the goals mentioned above. The difficulty that arises with this situation is that as soon as more than one goal is being pursued at the same time, it can quickly happen that one measure helps to achieve one of the goals but blocks another. The decision to act is becoming more complex as a result and currently represents a major challenge for experts and politicians.

In connection with the objectives defined above, two questions arise which make the process a major challenge. The first, is the question about the experts. Which experts should be involved in the discussion on measures and to what extent? Only after the first question has been clarified and the selected experts have worked out why which measures should be considered to a greater or lesser extent does the second question come into play. The decision questions. As the name suggests, this is the question of the decision, the decision as to which of the measures will ultimately be implemented and how consistently.

Back to the first question, the expert question. Scientists such as virologists or epidemiologists, further referred to as first-degree expert, are investigating at full speed what factors could influence the transmission and thus the spread of the virus. Factors that have already been discussed among experts include the survivability of the virus on different surfaces, the influence of more or less air circulation in rooms, the effect of a distance of one point five or two meters and so on. Once first-degree experts have gained insights into such factors, for example that the virus has a significantly reduced chance of being transmitted to another person if there is a strong air circulation in rooms, this results in a corresponding need for action. How this need for action actually looks like in practice can then be assessed not so much by a virologist for example but rather by a ventilation technician. In such a case, a second-degree expert, the ventilation technician, would have to be consulted at this point when discussing possible measures. This example illustrates how the question of experts can already quickly expand in the wake of new findings. Experts of degree one and two, who are mainly focused on finding effective measures to contain the virus however are opposed to those (third-degree experts) who should assess the social, societal and psychological consequences of the discussed measures. For example, they assess the impact of the lack of school and kindergarten time on the development of children, the impact of the lack of visits to hospitals and nursing homes on the elderly and sick, and so on. A good example to draw the connection between experts of all degrees, is the discussion on the obligation to wear masks. Virologists (degree one) say that coughing, sneezing and spitting are significant ways of transmitting the virus. Further research has shown that wearing masks reduces the risk of spreading the virus by coughing, sneezing, spitting as well as the risk of receiving it through the scattered droplets. Designers (degree two) could then be involved to create the most usable masks. With this, experts (degree one and two) had found an effective measure for containment of the virus and brought the discussion about the obligation to wear masks into the discussion. On the other hand, degree-three experts say that wearing a mask in everyday life is a massive restriction for people. People would not feel comfortable and many would therefore continue to do only the most necessary things.

It seems like when working in favor of one of the desired objectives presented at the beginning of this paragraph, enabling people to go about their daily lives as far as possible, getting the economy going again, giving a feeling of security or reducing the risk of infection, one often at the same time negatively affects another objective. In the example, the compulsory masks measure clearly has an effect on the reduction of infections, and perhaps also on the feeling of safety. At the same time, however, compulsory masks also seem to inhibit normal everyday life, people's desire to buy and thus the economy. The variety of perspectives offered by different experts therefore seems to be indispensable in order to identify all potential effects of the discussed measures.

Now we come to the second question, the decision question. The starting point for the second question is as follows: Factors affecting the transmission or spread of the virus have been determined by first-degree experts. In cooperation with second-degree experts, practical, implementable measures were then developed. The measures brought up for discussion are then also assessed by third-degree experts and concerns are expressed about the impact of the measures on humans. Now the advantages and disadvantages of all possible measures are on the table, a decision as to which measures exactly are to be implemented is still far from being made.

At this point the process leaves the responsibility of the experts and moves on to those who have to make the decision, the politicians. They now have available which measures support which of the goals and which others they block. So, if you decide to implement a measure or not to implement it, you automatically neglect one of the other goals. To come back to the example of the mask obligation. If one implements the mask duty, one neglects the goals of enabling people to lead a normal life and to get the economy going. If one does not implement it, one neglects the goal of providing security and reducing the number of infected persons. Thus, the pursuit of several goals at the same time leads to a wide variety of possible measures and thus ultimately to a decision to weigh up the options.

If one takes a closer look at these weighing up decisions, it becomes clear that these decisions are not only decisions about which measures fulfill the defined goals in the best possible way, but also decisions about how many infected and thus ultimately dead people one is willing to accept for the benefit of other goals. If one would not want to accept a single death from the coronavirus, this would have to result in a complete lockdown from detection to elimination of the virus. However, we humans do not, in principle, approach such problems with this attitude, and in the case of Corona it is also clear that such an approach is out of the question in the long term. The following example shows how to deal with a similar kind of situation that we encounter every day. For our freedom to be mobile we accept a certain amount of traffic fatalities every day. Here, freedom is restricted in so far as people who are under the influence of drugs, have very poor vision or other traffic endangering restrictions, lose this freedom. We are therefore restricting our freedoms because we are not prepared to accept this level of risk of road deaths. Politicians in the Corona crisis are also currently having to deal with such a weighing up decision. To what extent are we prepared to restrict our freedom in order to reduce the number of infections and thus reduce deaths? Anything is possible, from a decision for a complete lockdown and thus minimizing the number of corona infected and corona deaths to a complete restoration of the conditions before corona and thus accepting undirected infection and death. In such an unfamiliar situation, choosing exactly the right mediocrity is an unimaginable responsibility for the decision makers.

How such a decision should be made is unclear, because everyone weighs the goods individually. A single young man, for example, may be willing to limit his freedom very little, because his life fulfillment is strongly tested by celebrating and going among many people. A man whose wife is in an intensive care unit in hospital, on the other hand, probably demands a much greater restriction of personal freedom in order to protect the sick and aging, since his life fulfillment is strongly influenced by his wife, who would probably not survive an infection with the coronavirus. What is for sure is that in order to make a socially supported decision, a robust majority of the population must feel represented and represented in a decision. The prerequisite for this is that people express their opinions and needs and discuss them publicly. These in turn must be studied and analyzed intensively in politics in order to find viable compromises.

What makes the whole decision process even more difficult in the case of Corona, is that first we can only estimate the extent to which the shifting of goods effects the numbers of corona infections very limitedly and second people cannot imagine things that have never happened to them. On the one hand the concession of more freedom and the acceptance of more Corona deaths could go totally wrong and numbers of infections and consequently also number of deaths caused by infections could suddenly rise to much higher levels than ever expected. On the other hand, the implementation of very strict measures can also have its hurdles. When politicians impose such measures, they do so because they expect a development which they want to decelerate or prevent. In such cases in can either happen that the expected event never occurs or that the event could be prevented entirely, people thus did not get confronted with any consequences and therefore cannot imagine what would have happened if no measures would have been imposed. In both cases it is likely that politicians are blamed for unnecessarily restricting the peoples' freedom. Thus, decisions in both directions, relaxing measures as well as implementing strict measures, remain attempts with a set of unpredictable consequences.

Coming to the second part of the initial question on how any kind of experts in charge should exactly fulfill their task, it may be stated at first, that no uniform procedure currently appears to be discernible for this issue either. In theory, the following two opposing strategies can be discussed. The first approach considers the task of experts to be pure scientific. Which means that these only present their fact-based research results and also openly communicate open questions on which no knowledge has yet been gained. This attitude also implies that the interpretations and conclusions regarding instructions for actions and concrete measures are left entirely to the persons carrying them out, i.e. the politicians. The second approach defines the experts' tasks much more broadly and allows them to function as active advisors alongside the politicians. Beyond the research activities, they should publicly interpret their findings and actively speak out for or against what they consider to be sensible or not sensible measures or even propose such. (Kriesl, 2020; Zinkant, 2020)

Both strategies have their advantages and disadvantages, which must be considered before making a judgement. The pure scientists rely exclusively on their area of expertise and leave no room for speculation. Thus, they are always on the safe side and do not risk lose their trust. Only then and only about what is certain according to the current state of research is talked about. On the other hand, this approach runs the risk of being more cautious and delaying the resumption of "normal life" for an unnecessarily long time and thus weakening the economy even more and destroying more livelihoods. This could put experts in the position of unrealistic scientists who do not take the need for many people to return to a normal life seriously and thus endanger their existence. An aspect to be considered on side of more consulting scientist is that, people long for reliable clues as to how best to behave in such a situation. If these instructions do not come from experts, they will most likely come from politicians. Whether politicians recommend the more trustworthy and technically more competent measures is questionable. More actively advising scientists see their task in applying their great competence and experience in practice and to position themselves clearly in discussions. A clear positioning based purely on facts is not possible in the current situation, we have too little comprehensive knowledge and too many references. This means that making concrete recommendations for action must always contain a trace of speculation and riskiness. Findings are never sure and there is always the possibility that certain recommendations turn out to be wrong in retrospect and negatively influence the course of the crisis. The experts therefore run the risk not only of gambling away people's trust in them, but also of causing massive damage. However, it must also be noted that this wrong decision could also be made by politicians as a result of their interpretations derived from advice by a purely scientific expert. If the instructions prove to be correct, trust in the experts will naturally grow and the probability that people will continue to work with a great deal of conviction and more certainty in the future is higher.

Data jungle: What should we rely on?

Experts are nowadays confronted with multiple research studies and resulting findings from those. Currently, it sometimes seems that science is contradicting itself. This is put into perspective and can be explained if you take a closer look at on the basis of which numbers exactly studies have been carried out. For example, comparing numbers of the mortality rate from different sources with each other, can lead to confusion and contradicting results. Depending on how, at what time and in what period numbers have been collected results can differ a lot. If only people who have died in hospitals are counted compared to a study including all death caused by Covid-19, of course numbers deviate. Similarly, the mortality rate on a Sunday compared to the one on a Tuesday does not represent a realistic comparison, as a lot less death are reported on Sundays and are retrospectively reported on Mondays and Tuesdays. These results in turn will then be interpreted differently might even lead to different conclusions. Despite of this data jungle experts still remain the ones with the broadest knowledge to decide on where crucial differences and therefore major insecurities are. And on which questions only statistical deviations in the research approach seem to make a difference but there is actually broad agreement on. (Richardson & Spiegelhalter, 2020; Watzel, 2020)

Above all aspects that complicate the evaluation of the data, there is also the fact that none of the existing data is stable with certainty. Sometimes what is true for today, is far from being true for tomorrow. Therefore, basic assumptions about the virus can potentially change completely within hours. One example of this is the American virologist and government advisor Anthony F. Fauci. In a study published in the New England Journals of Medicine on March 26th, Fauci compared the consequences of the virus with those of a severe seasonal influenza. Three days later he strongly warned of Covid-19 and said that there was a danger that millions of Americans would be infected, and hundreds of thousands would die (Boseley, 2020; Watzel, 2020).

Three aspects in particular obscure our view on today's data.

The first aspect is that numbers gathered during a pandemic can always only represent a snapshot of the whole. The extent of risk and danger posed from the virus can only be determined afterwards by means of a holistic study which includes all collected data and interprets those as a whole. At the moment, science can only provide us with pieces of the puzzle. We tend to want to draw conclusions about the whole from these pieces. This puts the scientists in a difficult situation because rash assumptions as well as too much reluctance can create a wrong impression and ultimately lead to wrong actions. In order to bring together the many pieces that are currently created in research around the world and to offer them a unified platform, the WHO is currently working on a global study. The study "Solidarity II" is intended to make facts and figures from several severely affected countries comparable and then evaluate them. The aim of the study is to find better answers to especially two questions. Firstly, how can we design the most effective measures in the future? To this end, the study aims to use particularly broadly-based figures on the distribution and mortality rates of COVID 19 in different age groups. And secondly, how do we bring a drug or vaccine to market as quickly as possible? In this context, "Solidarity II" is expected to become the largest database for global knowledge about antibodies against COVID 19 within the next few weeks. (Vogel, 2020; Watzel, 2020)

The second aspect that makes it difficult to assess the current data correctly, is that until March 20th there was no uniform case definition by the WHO. A case definition is ought to specify the conditions under which someone is entered as a case in a statistic. Such conditions could be only including people with positive test results in studies. Other conditions might also include everyone who has stayed with an infected person showing Covid-19 typical symptoms. Consequently, all numbers gathered about COVID 19 without categorizing them according to a uniform definition could have potentially been recorded in studies under completely different circumstances. This in turn would make it almost impossible to compare these numbers and draw broader conclusions from those. The definition now in force since March 30th, defines that only persons with a laboratory confirmed Covid-19 infection, regardless of clinical signs and symptoms are to be considered as cases.

The third aspect deals with the lack of test capacities and the resulting unregistered cases on the data. In Hubei, China, at times the test capacities were so exhausted that patients had to show strong abnormalities such as fever in order to be registered as a COVID 19 case. The Hong Kong-based newspaper "South China Morning Post" wrote, citing confidential government documents from Hong Kong, that this meant that one in three known infections were not made public because patients did not show clear symptoms. In Germany the number of untested and consequently unregistered but infected people is expected to be much lower. These differences in the test capacities and consequently in the detection of infected persons also have enormous effects in communicating the danger of the virus to the outside world. For example, in countries such as China and Italy, which were heavily affected by Covid-19 before Germany, relatively much less testing was carried out. This meant that fewer symptom-free infected persons were detected, which in turn led to a significantly higher mortality rate. For weeks, these high death rates circulated in the media, were compared with values from other viral diseases and caused fear. When the virus started to spread in Germany and Germany began publishing their figures, many people were surprised about the relatively low death rate compared to other countries. Today, it can be assumed that this difference is due to the higher testing capacities in Germany and that therefore in fact the mortality rate is also significantly lower in other countries. The more symptom-free people are detected the lower the mortality rate. (Feldwisch-Drentrup, 2020; Gillmann, 2020; Watzel, 2020; WHO, 2020)

The constantly changing data over time in combination with the incompleteness and inconsistence of those makes it difficult for experts to make concrete and reliable statements. They always run the risk that they will no longer be up to date just a few days later. This in turn is again closely related to people's trust in the experts. How often can experts change their assessment without losing people's trust? Or is it better not to make any or only very vague statements?

C) Was the epidemic a surprise?

1. When have pandemics been an issue in the past?

Over the past 100 years several pandemics such as the Spanish flu, the Asian flu and SARS have challenged societies around the globe. The question arises if lessons learned from those pandemics can help us today to cope with the Covid-19 virus. For example, are there any parallels between today's situation caused by Corona and 100 years ago when the Spanish flu as the biggest pandemic of modern times wiped out more than 50 million lives worldwide? Or what conclusions can we draw from 1957/58 when the Asian flu as the second largest pandemic of the 20th century hit Germany and due to a lack of preventative measures caused by a policy of appeasement approximately 30.000 people (Paál, 2020) died in Germany? Since the 2003 SARS epidemic, it seems to be clear to institutions worldwide that a new, modified virus can emerge any time. As already mentioned in part B, knowing about the general risk of global pandemics is not hard but forecasting the specific time those could emerge is a difficult task to handle.

Spanish flu:

Comparing today's Corona situation to the world 100 years ago is difficult, because many things have changed since then. Back in 1918 the First World War raged and so the Spanish flu hit an already weakened world. Within a few months the Spanish flu spread from the USA worldwide. Carried by American soldiers to Europe, the Spanish flu spread with ease at the war front. Due to the much shorter incubation period compared to today's Corona virus and the fact that hardly anything was known back then about the Spanish flu, not even the pathogen itself, more people died by the Spanish flu than by the First World War itself (BR, 2018).

Asian flu:

In early summer 1957 the Asian flu, originating in China hit Germany. Back in the days Bremen's medical director of the health department claimed in a broadcast of Radio Bremen that there was "no reason for concern". He was convinced that "even the term 'Asian flu'" would be "a dramatization." He should be proven wrong. Four month later in October 1957 infection rates shot up and doctors and nurses were completely overloaded with house visits.

SARS epidemic:

Similar to today's Covid-19 virus, the SARS-virus originated from China in November 2002. Originating from the Chinese province Guangdong, in early 2003 the severe acute respiratory syndrome (SARS) spread worldwide carried by passengers on intercontinental flights. The spread of the SARS-virus was supported by the fact that it took the Chinese government up to the 10th of February 2003 before it informed the World Health Organization (WHO) regarding the ongoing events (tagesschau, 2020). Beforehand China tried to conceal the outbreak of the SARS-virus by imposing restrictions on the local press and censored reports of the disease. This method is strongly suggestive of what happened in China at the end of 2019 regarding the Covid-19 virus.

Similar to the new Covid-19 corona infection, the SARS disease begins like a severe flu. The affected patients usually face breathing difficulties, high fever, headaches, sore throat and muscles, and later possibly pneumonia. The incubation period of the SARS virus is about two to seven days. Equally to the Covid-19 virus, the

SARS pathogen was a previously unknown virus belonging to the corona virus family. This virus family is responsible for one quarter to one third of all flus.

Up to today, it has not been finally cleared why the SARS virus appeared so suddenly. Researchers suspect that the SARS virus which exists harmlessly in animals such as chickens, mice, cattle, pigs, dogs and cats mutated when transmitted to humans and by doing so became dangerous. Again, this sounds a lot like the explanations we hear nowadays in the news regarding how Covid-19 arose. Before the outbreak of SARS, scholars perceived corona viruses harmless to humans because they would just cause common flus (Uhlmann, 2012). But this has changed since the outbreak of SARS.

During the SARS-epidemic more than 800 people worldwide lost their lives before on May 25th, 2004 the World Health Organization officially declared the end of the SARS-pandemic.

2. How did we prepare for new pandemics?

As already touched on in the introduction to part B some precautions were implemented in order to prepare for new pandemics but to a limited degree to keep their maintenance cost or respectively the storage cost for medical gear low. Worldwide the World Health Organization (WHO) and the Bill & Melinda Gates Foundation (Gates Foundation) were key players and mainly act to build bridge between nations and to make them aware that they need to be prepared for new pandemics and should develop national pandemic plans. Therefore, new standardized warning and crisis management systems such as the WHO's Global Influenza Surveillance and Response System (GISRS) were established (WHO, n.d.). In Europe the European Centre for Disease Prevention and Control (ECDC) also cooperated tightly with the WHO to help prepare its European members for a future influenza pandemic (European Parliament and Council, 2004). This cooperation mainly took place between 2005 and 2008 after the SARS pandemic in 2002/2003 had proven to the world that a new influenza outbreak could happen anytime and would likely happen again. This leads to projects like the Common Ground on how different institutions would cooperate in a threating situation, such as an outbreak of the pandemic (Kaiser, Ciotti, & Simpson, 2005). The European member states clearly benefited from the European precautions when in 2009 the swine flu hit, and they were able to cope better with it than other parts of the world. But still there was room for improvement regarding communication, development and supply of vaccines and the ability to cope with a variety of different out-break scenarios.

Frameworks like the International Health Regulations (IHR) developed by the WHO in 2005 provide guidance how to declare a pandemic, the European Influenza Surveillance Network (EISN) has a similar function tailored to Europe's needs (WHO, 2007).

Building on the IHR requirements the Asia Pacific Strategy for Emerging Diseases and Public Health Emergencies (APSED III) helps especially Asian countries to prepare for pandemics (WHO, n.d.). Nowadays the WHO's Health Emergencies Program (WHE) is designed to work with member states to help them to prepare for large-scale outbreaks and pandemics.

As the Gates Foundation has been working on reducing inequalities in health and the risk of infectious diseases worldwide for about 20 years, it also took actions dealing with the current Covid-19 crisis by providing more than $250 million as a rapid response to sup-port relevant institutions which are fighting the challenges caused by Covid-19 (Suzman, 2020).

3. What was the so-called Spanish Flu in 1918?

In 1918, a strain of influenza known as Spanish flu caused a global pandemic, spreading rapidly and killing indiscriminately. Young, old, sick and even otherwise healthy people all became infected and around 10% of patients died. Though estimates vary on the exact number of deaths caused by the Spanish flu, it is thought to have infected a third of the world's population (Burnet & Clark, 1942; Frost, 1920), and killed at least 50 million people, making it the deadliest pandemic in modern history.

The outbreak began in 1918 during the final months of World War I which may have been partly responsible for spreading the virus since soldiers were living under horrible conditions in cramped, dirty and damp military positions and so became easily ill. This was also a direct result of weakened immune systems due to an ongoing lack of sufficient supply of nutrition at the war front. There, the Spanish flu, which were back then known as “la grippe”, was very infectious, and spread among the ranks. Within around three days of becoming ill, many soldiers would start to feel better, but not all would make it (LiveScience, 2020).

The influenza of that season, however, was far more than a cold. In only two years, a fifth of the world's population was infected. Surprisingly the flu was most deadly in young adults between the ages 20 to 40 who had previously been healthy (Simonsen et al., 1998). This pattern of morbidity was unusual for an influenza virus which usually affect the old and children the most (Billings, 2005).

The Spanish flu caused approximately 675,000 total deaths in the US alone (United States Department of Commerce, 1976) thus depressing the national average life expectancy by more than ten years (Grove, 1968). This probably has played a significant role in ending World War I (Crosby, 2003). As said earlier, estimations regarding a worldwide total death number differ. Crosby (2003), Johnson and Mueller (2002) as well as Paterson and Pyle (1991) came all to the conclusion that approximately 40 million people worldwide have died due to the Spanish flu.

This influenza pandemic of 1918 was exceptional in both breadth and depth. Outbreaks of the disease not only swept North America and Europe, but also spread as far as the Alaskan wilderness and the most remote islands of the Pacific. The disease was also exceptionally severe, with mortality rates among the infected of more than 2.5 percent, compared with less than 0.1 percent in other influenza epidemics (Marks & Beatty, 1976; Wallace, 2008).

As already mentioned above, in the 1918 Spanish flu pandemic most deaths occurred among young adults, a group that usually has a very low death rate from influenza. Influenza and pneumonia death rates for 15-to-34-year-olds were more than twenty times higher in 1918 than in previous years (Linder & Grove, 1947; Simonsen et al., 1998). The 1918 pandemic is also unique among influenza pandemics in that absolute risk of influenza mortality was higher in those less than 65 years of age than in those older than 65. Strikingly, persons less than 65 years old accounted for more than 99 percent of all excess influenza-related deaths in 1918–19 (Simonsen et al., 1998) This w-shaped mortality rate is shown in the figure below from (Taubenberger, Reid, Janczewski, & Fanning, 2001). Why this particular age group suffered such extreme mortality is not fully understood yet. One often cited explanation for this unusual morbidity pattern is that the 1918 H1N1 Spanish flu virus strain emerge from a former influenza subtype that circulated from 1889-91 and thereby enabled people born before 1889 to develop H1 antibodies, that later helped their immune systems to fight the Spanish flu (Dowdle, 1999; Ministry of Health UK, 1960; Simonsen et al., 1998; Taubenberger et al., 2001).

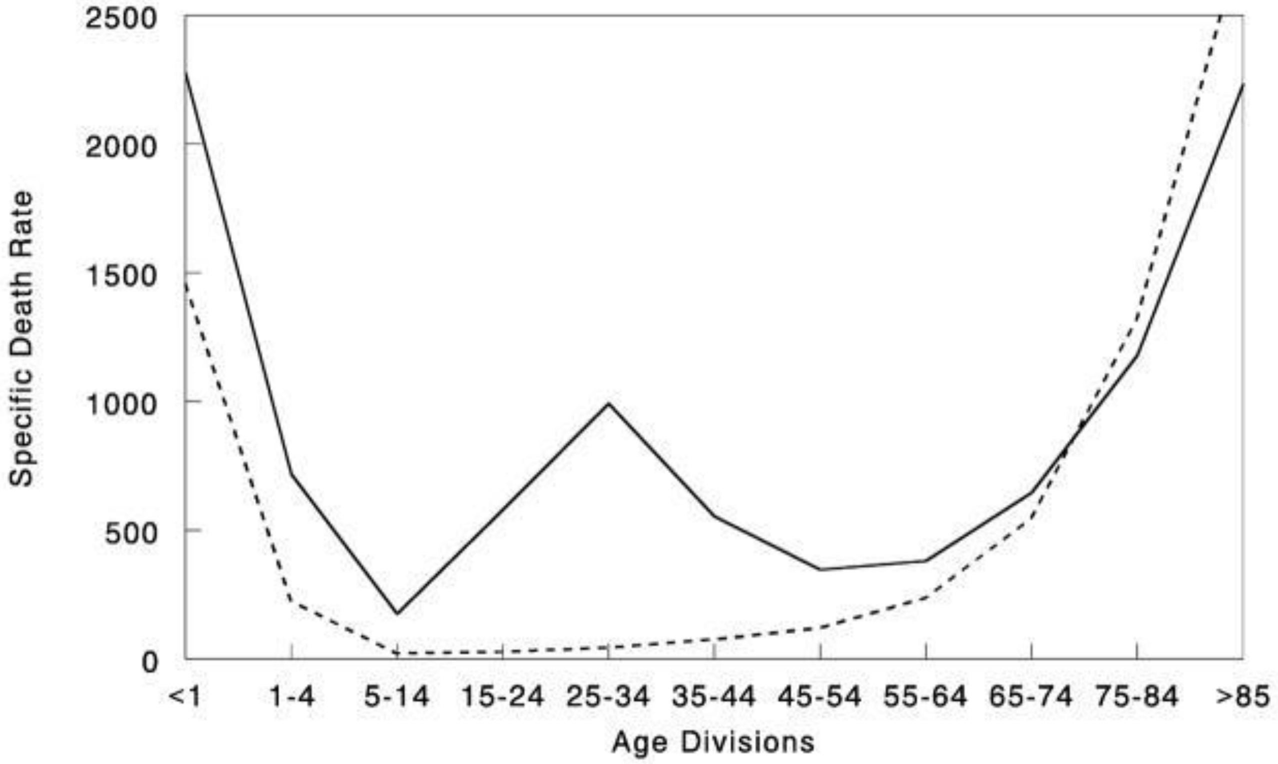


Figure C.1 – Title
Influenza and pneumonia mortality by age, United States. Influenza and pneumonia specific mortality by age, including an average of the inter-pandemic years 1911–15 (dashed line), and the pandemic year 1918 (solid line). Specific death rate is per 100,000 of the population in each age division (Grove, 1968; Linder & Grove, 1947; United States Department of Commerce, 1976).

4. How did epidemics factor into the colonization of the US?

In the years before European settlers established colonies in the New World, most Native Americans were living on the southeastern coast. With the arrival of European settlers, diseases from the old world started to spread among Native Americans leading to a many deaths especially between 1616 and 1619 (Cook, 1973). Yellow fever, plague, smallpox and influenza were common old-world pathogens carried by European settlers that Native Americans were lacking immunity towards (Hoornbeek, 1977). Those Microbes caused sickness and death everywhere Europeans settled. Along the New England coast between 1616 and 1618, epidemics claimed the lives of 75 percent of the native people ("Environmental and health effects of European contact with the New World," 2017). The loss of the most vulnerable - the young and the old - meant on the one hand the loss of knowledge and tradition for the Native Americans and on the other hand it took away their ability to reproduce themselves.

Similar patterns applied to the conquering of South America by the Spanish and Portuguese. All in all, exploring this topic in depth would exceed the constraints of this report which is why we will leave it at this short description.

Conclusion

In this report we have showcased some epistemological problems associated with the current Covid-19 crisis. To achieve this, we broke down how to measure the severity of a virus outbreak and illustrated our thoughts on common problems of testing for a virus and handling large infected populations with simple models. Then we compared the infection dynamics of Covid-19 to other, often seasonal, flus and explained wich factors enable Covid-19 to spread so fast on a worldwide scale. Afterwards we took a look at past pandemics, presented what they taught us and compared them to the current Corona-pandemic to see what measures could be suitable for our current position.

Our report is the first half of an academic group paper project conducted at the Frankfurt School of Finance & Management. The second half will cover different strategies, countries have used or may use to cope with the Covid-19 situation. This second part focuses especially on the country of origin of the virus, China, Sweden, Germany, Italy and South Korea. Furthermore, social and economic consequences are looked at to come up with ideas how to deal with them and to be able to develop a master plan to bring the social lives and the economy back to normality.

As this report is written by a course on epistemology, we tried to restrict ourselves to peer-reviewed scientific papers and articles from major international newspapers and established publishers. Please bear in mind that the available Covid-19 related data changes on a weekly or even daily basis so that some of the numbers presented here may be outdated when you read them.

Finally, we hope to have given a robust account of the discussion and available information surrounding some of the problems caused by the outbreak of Covid-19. Thank you for taking the time to read this paper and feel free to reach out to us, if you want to discuss our findings or criticism.

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