Statement on the COVID-19 Crisis

Summary of some quantitative Perspectives
(Update including the latest data of 31.3.2020)

Authors: Mathias Beiglböck (University of Vienna (Uni Wien), Philipp Grohs (Uni Wien), Joachim Hermisson (Uni Wien, Max Perutz Labs), Magnus Nordborg (ÖAW), Walter Schachermayer (Uni Wien)

With the assistance of rectors Heinz Engl (Uni Wien) and Markus Müller (Med Uni)

Preface by the authors

This is the updated version of the so-called "Executive Summary", a summary of the current knowledge and assumptions on the spread of the Corona Virus and possible measures for further containment. The summary is based on a wide range of publically available national and international data and studies on COVID-19 and the observed effectiveness of various measures. Our focus lies in explaining standard models of the dynamics of epidemics.

In the current situation, which is characterised by a rapid development due to the exponentiality of the pandemic, it is a matter of priority to provide a rapid appraisal of these insights as a basis for necessary decisions. This is why the authors have in short term prepared this summary as a document to be presented on the table in the deliberations of the Austrian Federal Government on Sunday evening, 29.3.2020. Originally not intended for publication, the Federal Government has decided to make this document available also to the media.

The current update takes the developing data situation (status as of 31.3.2020 in the evening) into account, and includes comments and suggestions made since then by the scientific community. The highly unpredictable development of the pandemic means that presumably until the end of the spread of COVID-19, statements will be of a provisional nature and constantly developed further in scientific discourse. These references are continuously made available in the Link at the end of this paper.

FACTS

The decisive factor for an epidemic is the basic reproduction number R_0. That is the number of persons infected on average by an already infected person. If the number is less than 1, the pandemic will subside with exponential pace. If it is higher than 1, the pandemic will invariably spread with exponential pace. If we do not rapidly succeed in pushing the factor below 1, **tens of thousands of fatalities and a collapse of the health system** is to be expected in Austria.

Some Asian countries have succeeded in preventing the outbreak of the pandemic altogether (Taiwan, Singapore) or in curbing an originally unrelentingly spreading epidemic (China, South Korea). These countries have managed to reduce the basic reproduction number R_0 from approx. 4 in the beginning to below 1. This was achieved by country-specific bundles of measures without causing lasting damage to the economy.

In Europe, there is little solid empiric evidence of a decisive reduction of R_0. The registered COVID -19 fatalities are de facto the only reliable data so far, permitting conclusions on the development of the basic reproduction number R_0. Its course is parallel with an approx. 14-day delay, to the course of the infections.
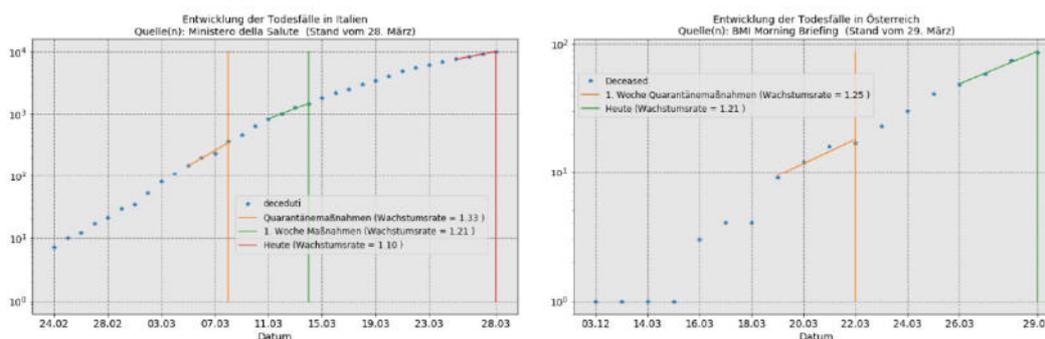
Development of casualties in Italy and Austria

An empirical glimmer of hope in Europe comes from Italy where severe restrictions were imposed on 9 March, one week earlier than in Austria. Hence, enough time elapsed for the restrictions to have a positive effect on the number of casualties. Fortunately, the relative increase of deaths per day in Italy has declined from originally 1.33 (three weeks ago) to 1.074 (average of the last 4 days).

A reduction of that figure below ~ 1.07 can be regarded as a first indication for reaching a basic reproduction number within the realm of $R_0 = 1$ (see Annex on mathematical principles). This rate was almost achieved in Italy for the first time on 31.3.2020. In order to have a chance of containing the epidemic on a permanent basis, the daily increases must subsequently also decline in absolute numbers.
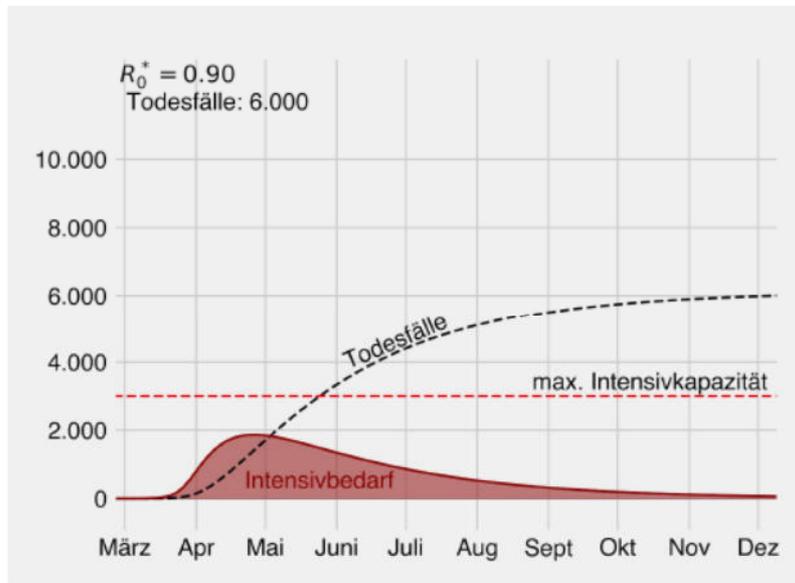
In Austria, the relative daily increase of fatalities declined from 1.25 to 1.20 since the introduction of the sanctions. These data are, however, subject to considerable statistical uncertainty, since the number of casualties in Austria is fortunately still low. The data are pointing in the right direction, but do not permit any valid statements yet.
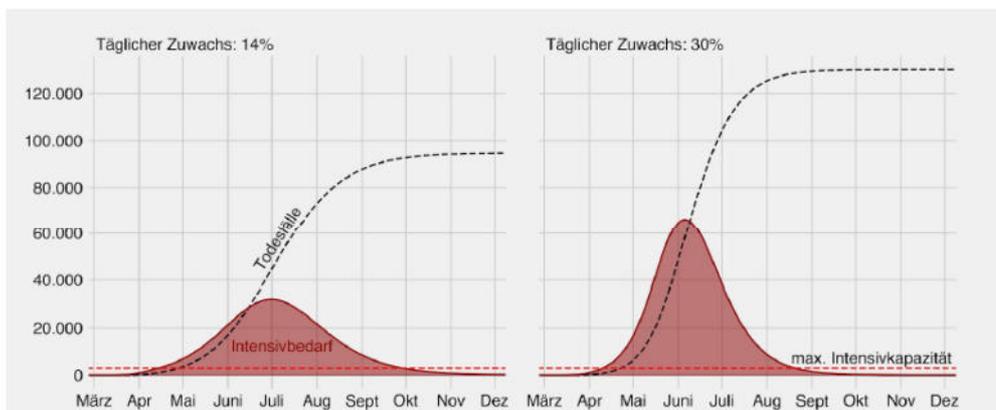
MATHEMATICAL MODELS

The internationally favoured epidemiological forecast model (our implementation relies on the SEIR models from Basel and Harvard) is based on a list of specifications for relevant factors (e.g. R_0). The development of the relevant epidemic groups (infected persons, diseased, patients in intensive care, fatalities) logically and invariably follows from these assumptions.

Like any mathematical model, it can only make "if, then" statements

We have adjusted the SEIR model to the Austrian situation. In case of a rate of $R_0 = 0.9$, there is for example, the following development regarding the need of intensive care beds and expected casualties:

$R_0^* = 0.90$
Todesfälle: 6.000

10.000
8.000
6.000
4.000
max. Intensivkapazität
2.000
Todesfälle
Intensivbedarf
0

März Apr Mai Juni Juli Aug Sept Okt Nov Dez

This development does, however, decisively depend on the optimistic assumption $R_0 = 0.9$. If we assume, however, that there will be a daily 14% increase of infected persons (as in the week from 21.03.2020 to 28.03.2020 in Austria) or 30% (as in the beginning of the epidemic), this results in the following development:

Täglicher Zuwachs: 14%

120.000
100.000
80.000
60.000
40.000
20.000
0
Todesfälle
Intensivbedarf

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Täglicher Zuwachs: 30%

max. Intensivkapazität

März Apr Mai Juni Juli Aug Sept Okt Nov Dez

The model easily permits an analysis of changes in the underlying specifications. In Annex 2 we have projected the development in Austria under the following two alternative specifications:

A.   Avoiding any transmission by health-care personnel (which requires regular testing, protective clothing, strict isolation)

B.   Health-care personnel as essential transmitter ("superspreaders") as observed in Italy (10% of all infected persons are healthcare workers, > 50 doctors died)

There is a strong effect on the excessive burden on intensive care units and the expected death rates in Austria.

This is just one example of how this model can be used to analyse the change of specifications. For an evaluation of other planned measures, this tool – ceteris paribus - can give analogous impact assessments at the push of a button.

RECOMMENDATIONS

A. Central Recommendation

The primary goal must be to push R_0 below 1. Under no circumstances should any hopes be raised for an early easing of the restrictions. Much stricter measures than those currently in force will probably be needed. Under the realistic assumption of $R_0 = 1.7$ (see also study of the Imperial College of 30.03.2020), our health system can no longer cope with the situation and the capacity of intensive care beds will be exceeded already in mid-April or end of April. There is hardly any time to prevent this.

The example from Wuhan also gives reason for hope: after China managed - in two steps – to push the value of R_0 to 0.32, the crisis was overcome within a few weeks.
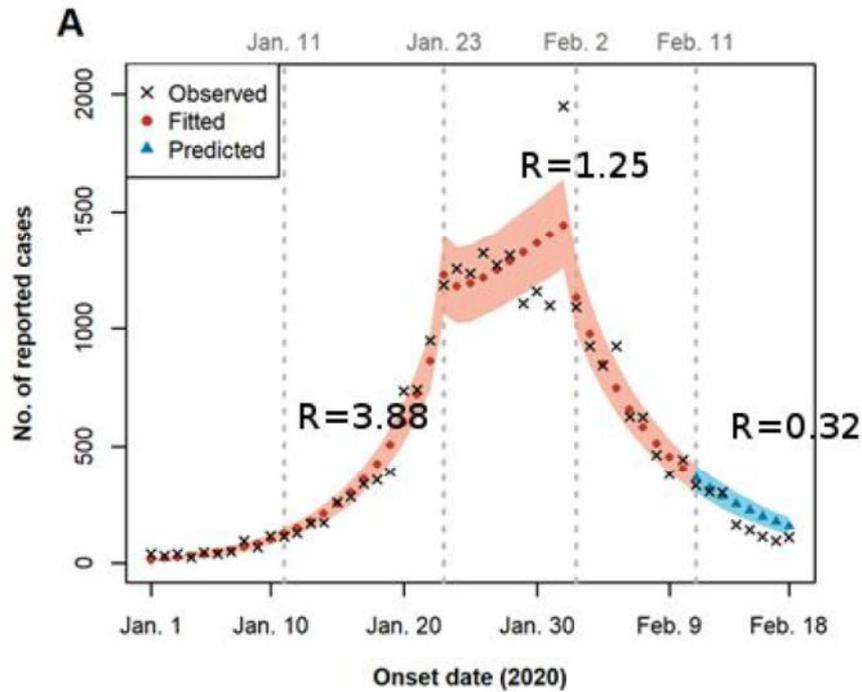
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The mix of restrictions (see the graphic "NPI Measures per Country" below for an overview of internationally imposed measures) can be changed. For example by imposing a duty to wear masks in public and increased testing. Both measures were implemented by all successful countries. But the overall impact of the mix on R_0 must by no means deteriorate.

All this certainly only applies until a comprehensive use of vaccines is possible.

B. The following suggestions are made for specific measures:

1. Rigorous implementation of the measures adopted so far: e.g. control of number of customers in supermarkets by security personnel, rigorous warning in case of non-compliance.
2. Special focus on medical personnel, in particular through regular testing. This would certainly be met with a positive response by this extremely exposed group.
3. Measures to curb infections by asymptomatically infected persons such as supermarket staff. Increased testing, including tests from research laboratories that have not yet been validated.

4. Increased use of facial masks (if supply is secured). Although the individual protection through facial masks may not be very high, the statistical effect on the spreading of the disease seems considerable.

5. Tracking the contacts of infected persons during the days prior to the test with the help of mobile phone data.

6. Risk groups and especially diseased with light symptoms should be better isolated. A food supply service should ideally be organised for the risk group.

7. Establishment of special "fever hospitals", i.e. facilities specifically reserved for Covid-19 infected persons.

NPI Measures per Country

Source: Matt Bell, Elena Baillie, Genevieve Gee, Tomas Pueyo

From Tomas, Pueyo, "Coronavirus: the Hammer and the Dance", available at
https://medium.com/@tomaspueyo/coronavirus-the-hammer-and-the-dance-be9337092b56.

LITERATURE (constantly updated)

https://docs.google.com/document/d/1E5Y614zSAsdC3PlWFXIovKC5rV3N2om0puxmYpPznAg/edit

ANNEX 1: SOME MATHEMATICAL PRINCIPLES AND CONCLUSIONS[1]

- The basic reproduction number R_0 is the essential parameter:

R_0 is the average number of persons infected by an already infected individual before he/she recovers or dies.

(To be precise, the number of persons infected on average by an infected individual certainly depends on how many persons are already immune. If, however, only a few percent of the population are infected, this effect can be neglected at the beginning of a pandemic).

- Meaning of R_0:

Assuming $R_0 = 2$, each diseased will on average infect two others. Within a "cycle", the number of infected individuals doubles. From 1 infected, to 2, to 4 and to 8, etc. After 16 replicates we have over 100,000 infected individuals. We are in the much-quoted phase of *exponential growth.*

In the case of COVID-19, we have approx. a rate of $R_0 = 2.8$ unless measures are taken. Our measures are always aimed at reducing R_0 as far as possible.

Especially important is $R_0 = 1$. In this case, every infected person infects just one new person. Since the infected recovers, the disease does not spread, meaning that the number of sick persons remains constant.

Generally speaking, the disease spreads if R_0 is higher than 1. The growth is first exponentially rapid. It will come to a standstill only as soon as the share of immunised individuals within the population is large enough. How large that share must be, considerably depends on R_0: If $R_0 = 2.8$, the infection will spread very far: the growth will only stop if some 65% have been infected.[2] If $R_0 = 1.02$, the growth will stop, if some 2% of the population have been infected.

On the other hand, if $R_0 < 1$, the disease will exponentially die out rapidly. This is certainly highly desirable.

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[1] The aim of this section is to present some principles considered important by us in an easily comprehensible manner. In particular, we cannot go into detail here regarding the modified SEIR model underlying the calculations in Part 1.

[2] If 65% of the persons encountered by an infected individual, are already immune, the diseased can only infect 2.8*0.35, i.e. approx. one new person. And since the diseased will recover, the disease does not spread.

- No reference is made in the media to R_0 but usually to the daily increase, in percent, of all persons tested positive. It is possible to calculate one rate on the basis of the other. This requires, however, assumptions based on the underlying model. For example, the important case $R_0 = 1$ in the case of Covid19 for a limited period means a further daily increase of all persons tested by some 7%.[3]

- Another common concept is the number of days it needs for the number of newly infected to double. The other respective rates can also be calculated on the basis of that number: A daily 20% increase corresponds, for example, to a doubling time of approx. 4 days.

Conclusions for Decision-Makers:

We only have a limited number of intensive care beds and respirators available, and that number can be increased to a limited extent only. That capacity will be saturated as soon as some 125,000 persons (1.5% of the population) are simultaneously infected. [4]

From that moment, we have to decide under which criteria patients should no longer be ventilated. The death toll would thus considerably increase.

Generally, we want to avoid exponential growth at all costs. As soon as R_0 is above 1 over a longer period, models for Austria predict some 100,000 additional deaths.

In the medium term there are two appropriate strategies:

1) Controlled achievement of herd immunity: the measures are always kept strict so that no more than 1.5% of the population is sick. This corresponds to a R_0 rate between 1 and 1.02.

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[3] In a simple SEIR model with $R_0 = 1$ and an infectiveness of 14 days, this results in a daily increase of some 7% in the beginning. For further details, reference is made to
https://docs.google.com/document/d/1sFmS5_5IhP--Q8-7Xtd0iXUWHx6lBjGTj73J248j-PI/edit?usp=sharing

[4] It is assumed that around 2% of those infected require intensive care (of whom around half die) and a maximum of ~ 2,500 beds are available for Covid19 patients. The precise figures also depend on the average duration of intensive medical care needed by patients and how much we can extend the capacities of intensive care units. If there is an exponential growth, an additional factor 2 in the capacities only means that they are saturated a few days later.

A problem of this strategy is that it takes relatively long (more than 12 months) for a sufficient herd immunity to be achieved. Another risk is that the immunity developed by convalescents towards Covid19 is not complete (there are first indications to that effect). It may well be that some convalescents can be infected again after one year. This challenges the idea of herd immunity.

2) If we succeed in reducing R_0 below 1 (e.g. $R_0 = 0.9$), the disease will exponentially die out rapidly. This strategy seems to have been successfully applied in China and South Korea. In case of a much lower number of cases, there is the possibility to isolate and test all suspected cases and their contacts (contact tracing). Here, the problem is that this method must be applied very consistently until vaccination or good medication is available.

ANNEX 2: TRANSMISSIONS IN THE HEALTH SECTOR

- Epidemiological SEIR model based on Covid-19 models of the University of Basel and Harvard University
- Adapted to Austria and adjusted to available data (numbers infections, intensive cases, fatalities, capacity of intensive care beds)

Modelled Scenarios

Motivation: **Doctors and health-care personnel can be "superspreaders" of the virus**

- Evidence from Italy, among others, that this constitutes a massive problem (10% of all infected persons are health-care personnel, > 50 dead doctors), estimated by WHO as "enormous threat":
- Three scenarios
    1. Transmission rate in the health sector analogous to the entire population
    2. Increased transmission rate in the health sector: superspreader scenario
    3. Total quarantine: protective measures and tightly meshed tests prevent any transmission in the health sector
- All three scenarios take the current lockdown measures in Austria into account and proceed on the assumption that those measures
    I. are effective thus resulting in $R_0 < 1$ (!)
    II. are maintained (!)

- The following picture emanates from that model: while the capacity of intensive care beds is fully saturated in scenario 1, a significant reserve remains in scenario 3. In scenario 2 there will, however, be a massive excessive burden on the health system with thousands of additional casualties.

Discussion
Transmissions in the health sector can be a massive problem, which on the basis of the current data is not yet visible in Austria (see, however, Italy, where it is already clearly visible). It is thus indispensable to do everything we can to ensure a safe quarantine:

1. Rigid and controlled separation of infected persons, including suspect cases. Especially in China, controlled quarantine was a very successful strategy.

2. Protection of doctors, health-care personnel (masks, protective suits). High risk due to high viral load, also younger doctors are disproportionally affected and can die.

3. Tightly meshed tests for health-care personnel in order to stop further spreading.

Model forecasts are highly dependent on factors not yet known today

- Here, a relevant factor is modelled as an example only (health sector). Other areas (e.g. supermarket staff) may also be relevant.

- With many factors, the effects cannot be visible in the data today (here: hospitals are gradually filling up).

- Safe model forecasts excluding such (highly realistic) risks, are therefore basically impossible.