The Corona Crisis and Related Mathematical Questions

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https://corona-prediction.de

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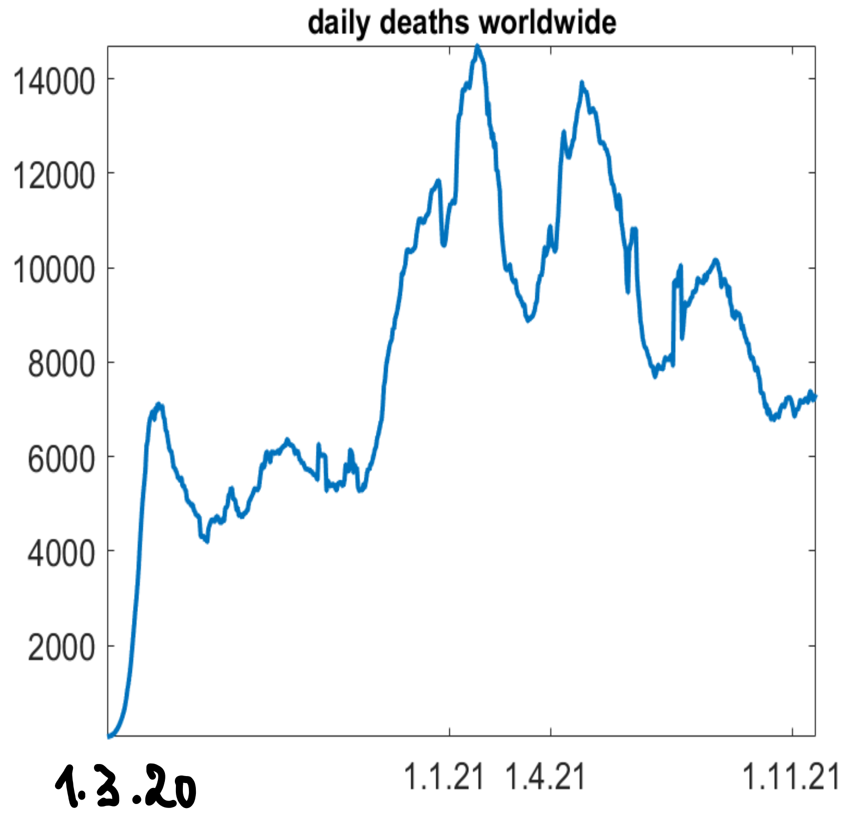
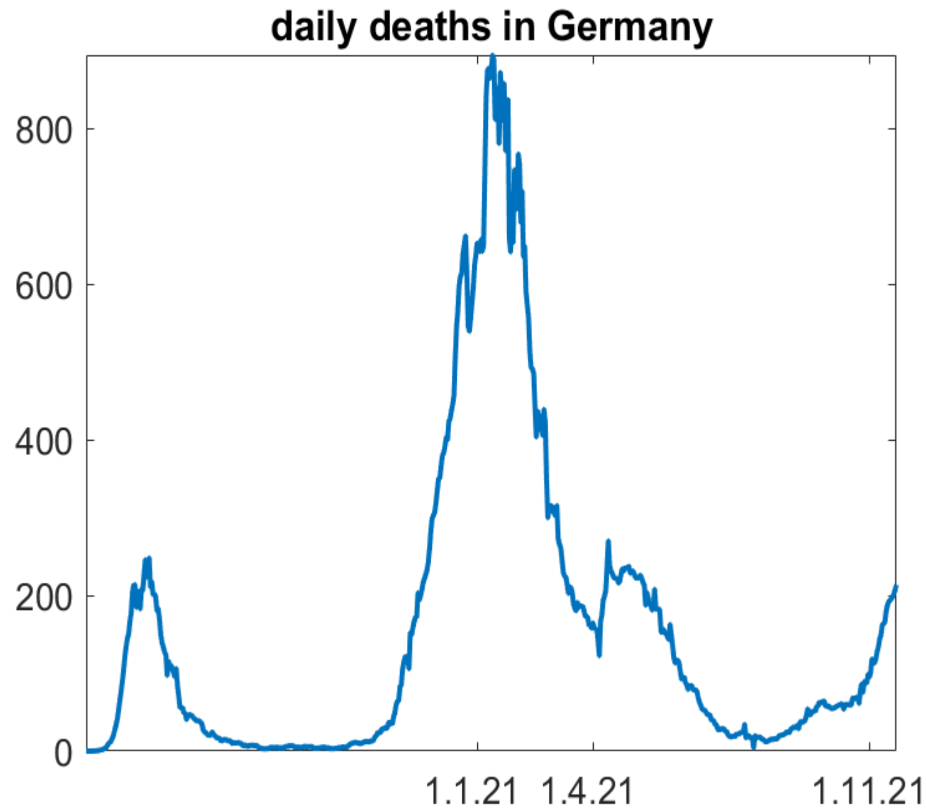
1. Overview
2. Basic parameters of the pandemic
3. Some mathematical problems

1. Overview

- Damage and danger of the pandemic
- Present situation and hotspots
- Remarks on data sources and mathematical understanding of the crisis

1.1 Damage of the pandemic in terms of deaths

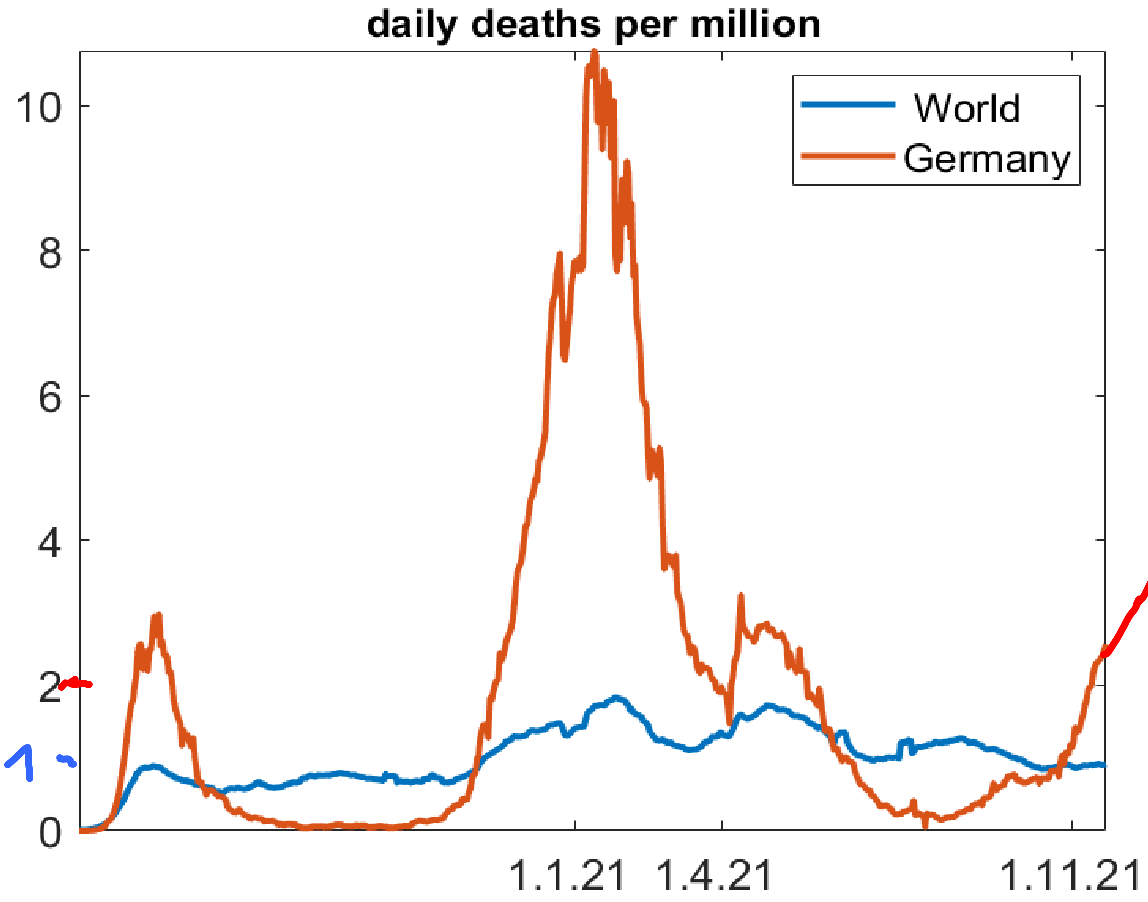




Each day, 8000 people in the world die with Covid-19.

In Germany, 200 die each day.

Relate to population size



Wave 1 2 3 4

Each day, one person in a million dies in the world.

← bad forecast

In Germany, two persons in average.

Relate to usual number of deaths

$\approx$ 20 of 1 million die each day in the world and 30 of 1 million die each day in Europe, on average

1 of 20 is 5%, and 2 of 30 is 6%, roughly.

Thus: the damage of Covid in terms of human life has been 5% of the average normal death rate worldwide, and 6% in Germany.

Actual value > 10%. After 3 weeks it will be 25%

Comparison 2020 and 2021

World: 8 billion people, 140 million births,
2021 60 million deaths, 3.5 million with Covid
≈ 6% of the usual death number
2020 2 million Covid deaths, ≈ 4%

Germany 2020 83 million people, 940 thousand deaths
34 000 with Covid, after March
< 3%
2021 66 000 Covid deaths so far 200 per day
7 – 8 %

1.2 Summary

Covid-19 is a dangerous illness. In spite of vaccinations, there were more victims in 2021 than in 2020.

However, the direct damage in terms of lives is not catastrophic. As a rule, Covid does not kill healthy people. When you are young and healthy, you need not fear the virus personally.

Old people, however, can catch many diseases.

The real danger to society: the coronavirus is so infectious that it can overwhelm the health system in a very short time.

This is what we see today: health offices cannot follow contacts, their phone is not available, there are no tests, vaccinations proceed slowly, all doctors are overloaded, intensive care units are full. $\Rightarrow$ a lot of pressure and trouble for everyone.

Example. 80 million people lose 20 minutes on a single day

$$80 \cdot 10^6 \cdot \frac{1}{3} \cdot \frac{1}{24} \cdot \frac{1}{365} \approx 3000 \text{ years of life}$$

The same amount of lifetime as when 300 people die who otherwise would have lived 10 more years.

This danger has been consistently underestimated by politicians.

Now we are in a big mess.

Only immediate hard restrictions can help.

However, restrictions do only work if they are accepted and controlled.

So they cannot be too hard.

And they will cost a lot of lifetime!

1.3 Sources of data

international: - Johns Hopkins university

- Our world in data (Oxford, supported by gates foundation)

Germany: - Robert-Koch-institute (dataset RKI-COVID19.csv, dashboard, reports)

- Divi-Intensivregister
- Zeit online

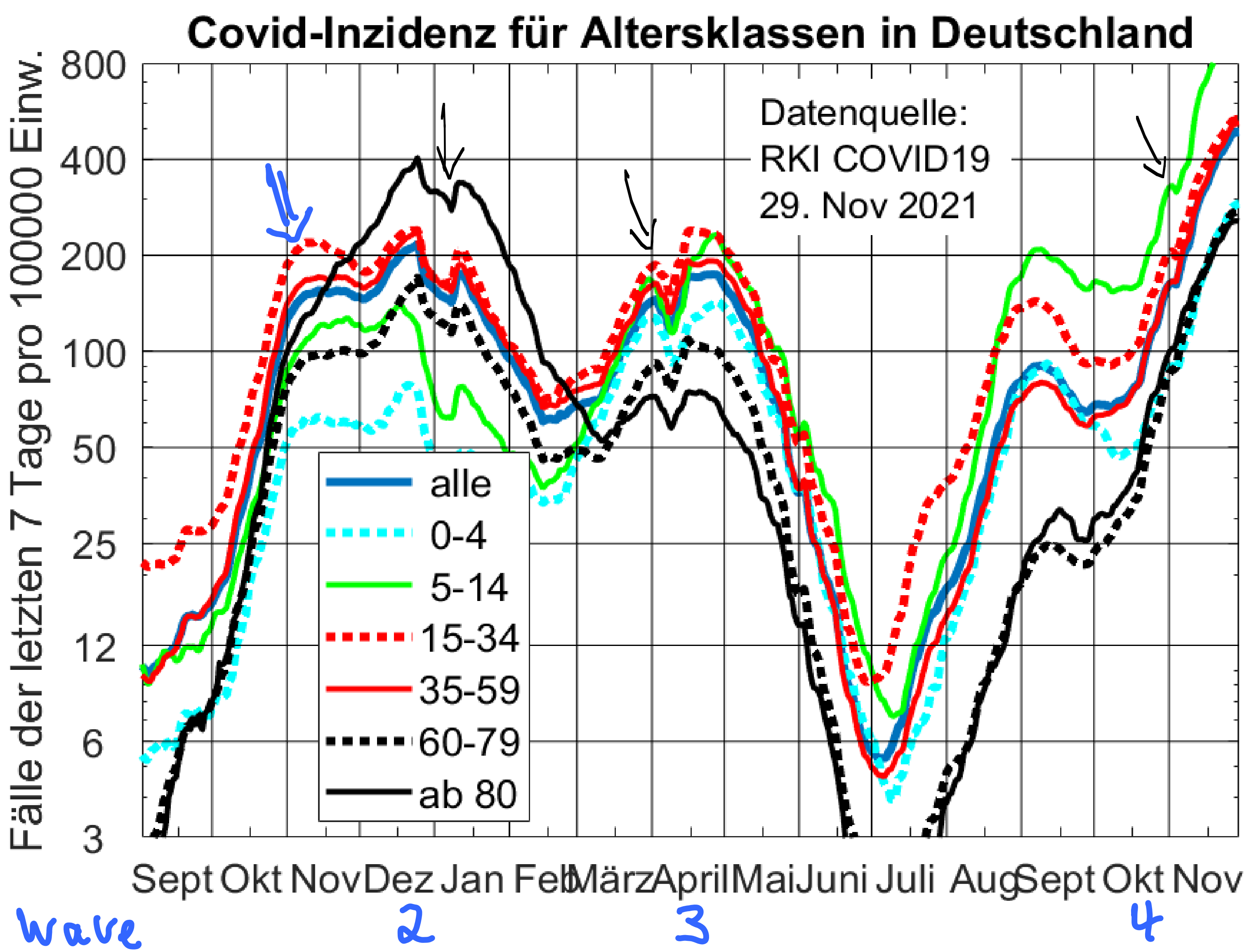
1.4 Important principle for mathematically understanding the pandemic

We cannot separate the pandemic from its observation. Numbers of deaths and cases are determined by the way they are counted.

Ex. Deaths reported today may have occured 2, 4 or 12 weeks ago.

Epidemiological models can hardly be fitted with data obtained by the administration.

1.5 Development of case numbers in Germany



effects of holidays

reduction of testing

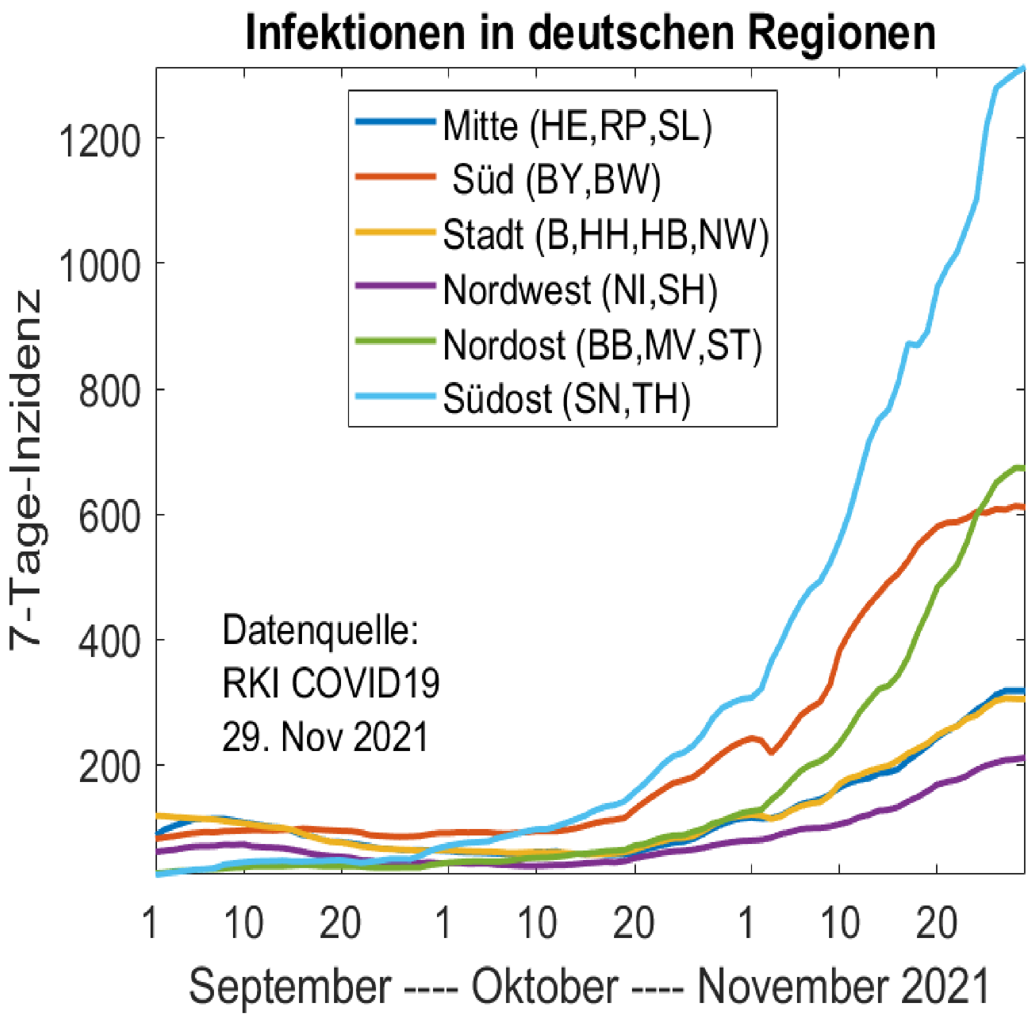
Situation today Germany 486, Bavaria <700, Saxonia 1500

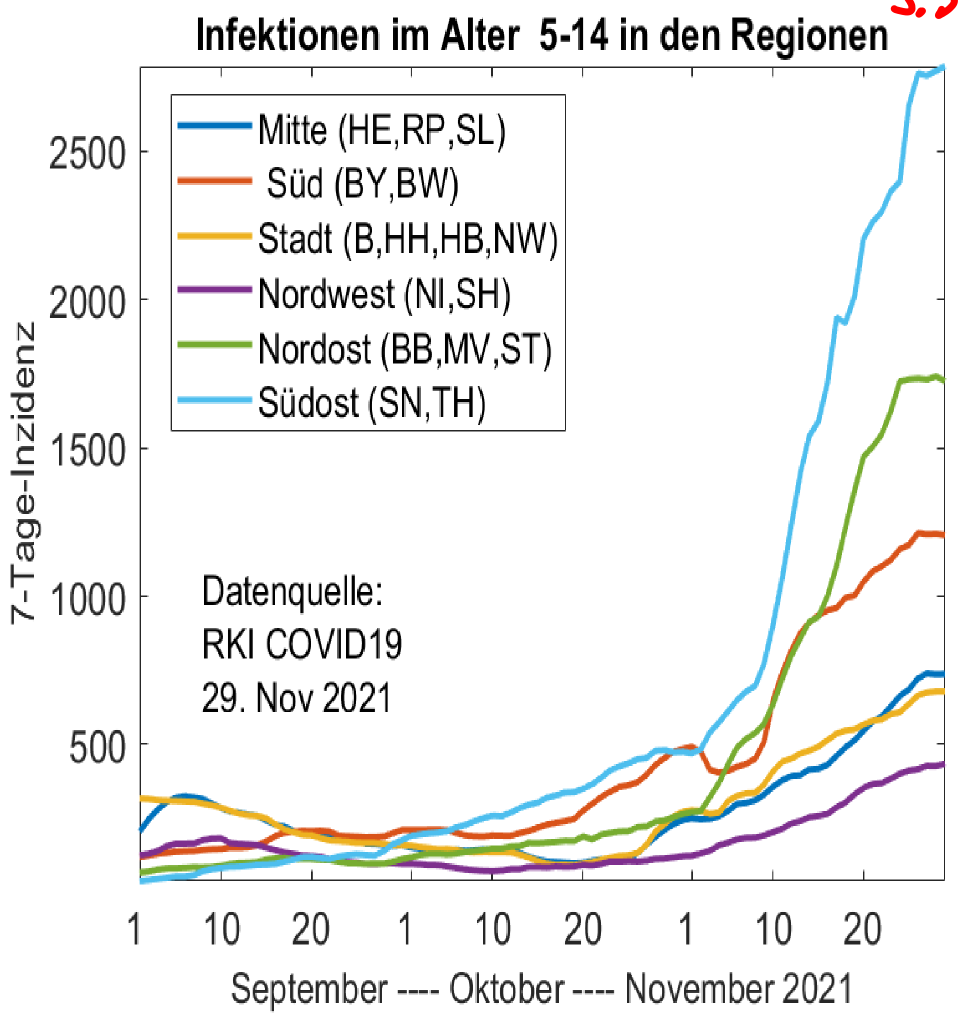
stopped?

pupils in Saxonia 3300

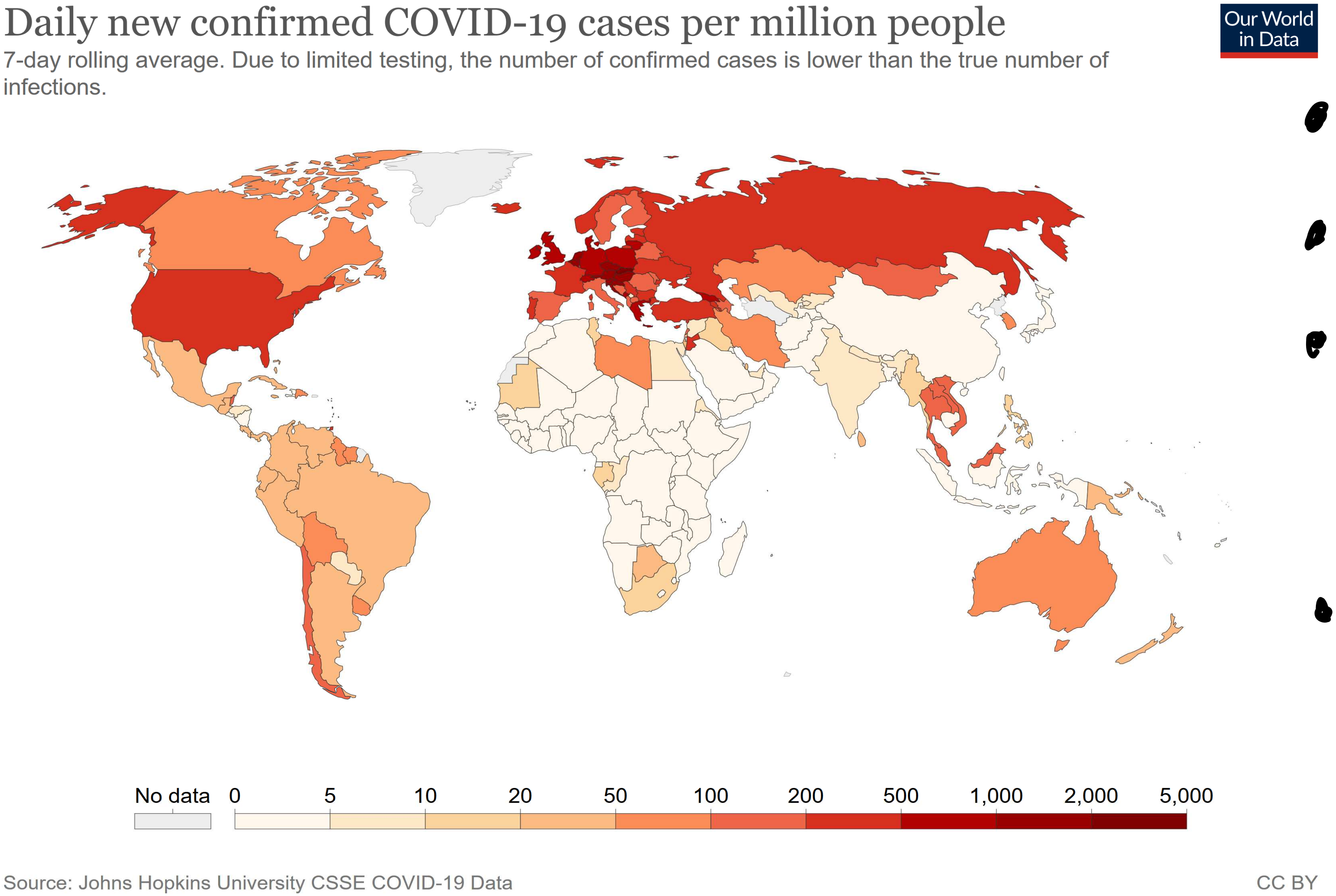
MV 430, VG 500

3.3%





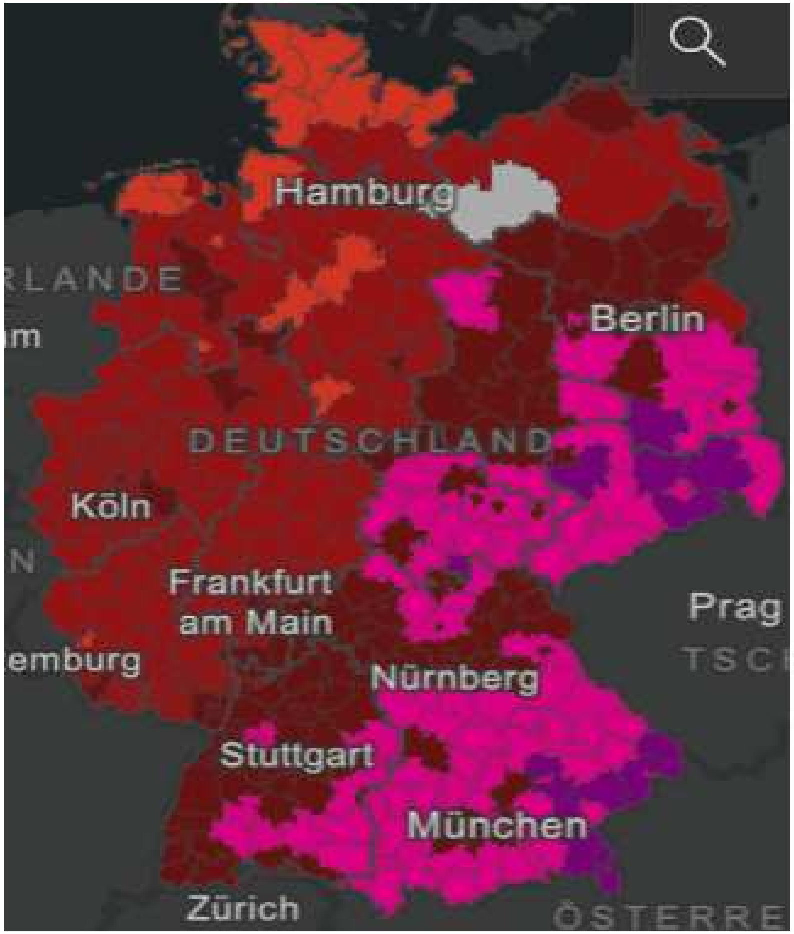
1.6 Current Hotspots of the pandemic

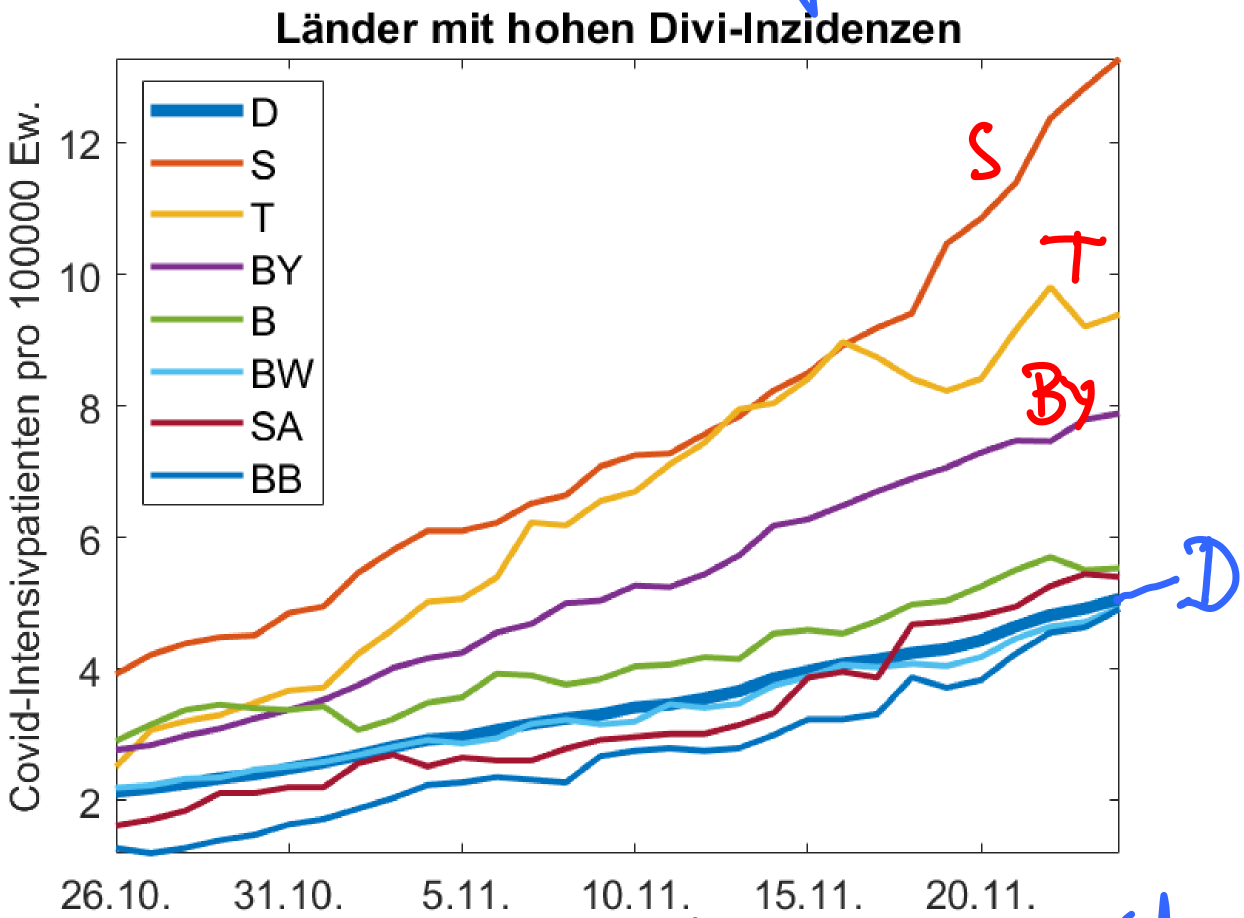


- Eastern Europe
- Russia
- Germany, Belgium, Austria
- USA

Germany: Saxonia, Thuringia, Bavaria

more general, South and East regions





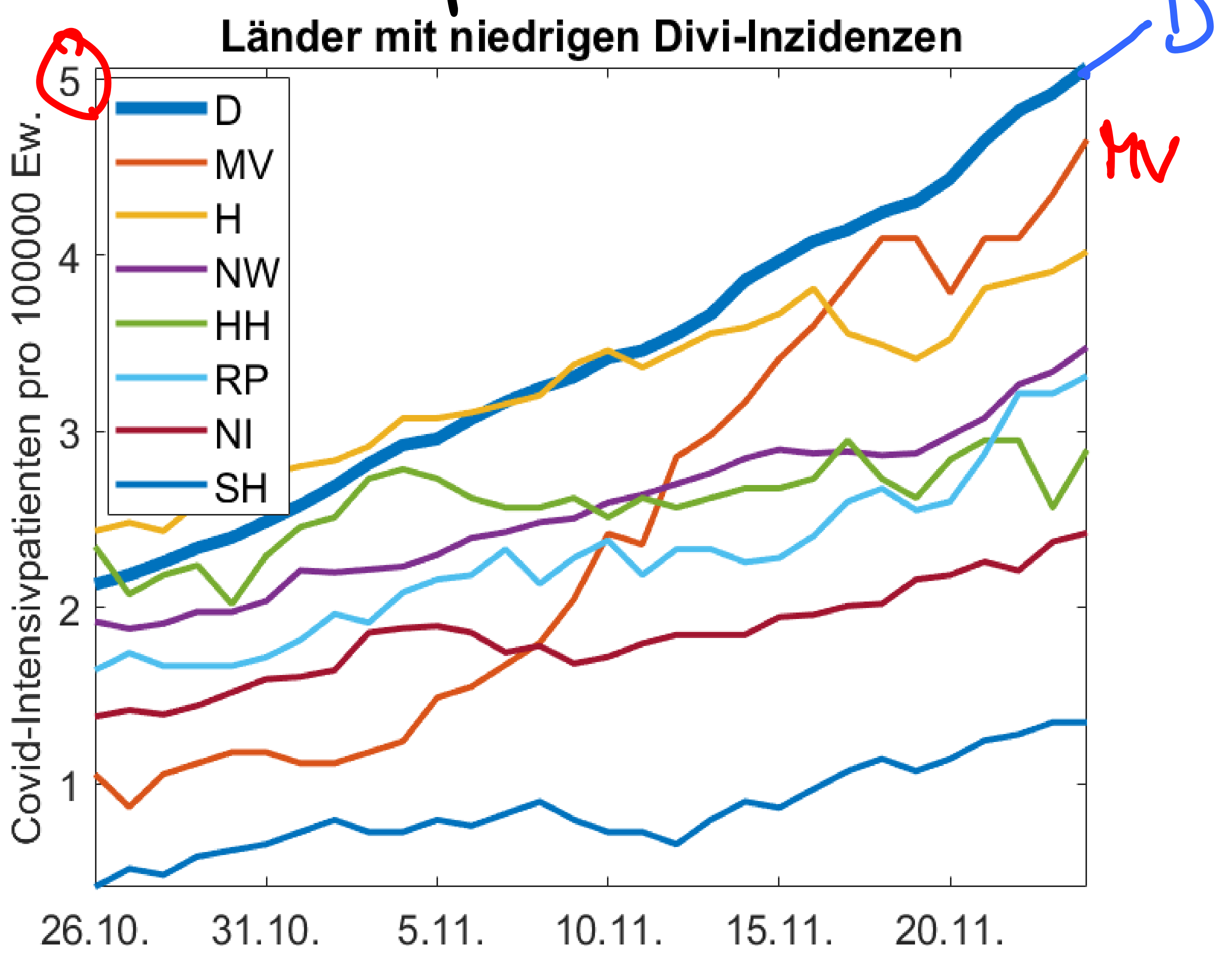
regions with high ICU incidence

number of Covid ICU patients per 100 000 inhabitants.

worst number in Jan. 21 was 8 for all Germany

Now already 13 in Saxonia on 24 Nov.

other federal states



2. Parameters of the pandemic

Cases
positive rate

Deaths
ICU patients
Hospitalization rate ??

Vaccinations
Government measures

Some international comparisons

2.1 The basic numbers of the pandemic

Deaths hard data, comparable for different regions and countries

but data reported very late (2-12 weeks after actual death date)

relate to population:

death incidence = weekly deaths per 100000 = $\frac{7}{10}$ · daily deaths per million

Rule (Europe) 1 weekly death per 100000 means 5% Covid of the usual death rate

Rule:
incidence 1000 means 1% of people are verified as infected

so 2-5% may be infected

Cases infected people verified by positive PCR test

reported early, few days after the test

basis for political decisions

but case numbers depend on the intensity of testing

are hardly comparable for different regions

weekly numbers indicate the strength of pandemic (typically, an infected person is contagious for ≈ 7 days)

Positive rate = share of positive tests
characterizes the intensity/quality of testing

WHO: $< 5\%$ means pandemic is well-managed

Germany, week 15-21 Nov (latest value reported)
20% Saxonia 38%, Thuringia 36%

Catastrophic values — testing was neglected for a long time

ICU incidence

(intensive care unit)

number of ICU Covid patients per 100 000 people

very important parameter, reported early

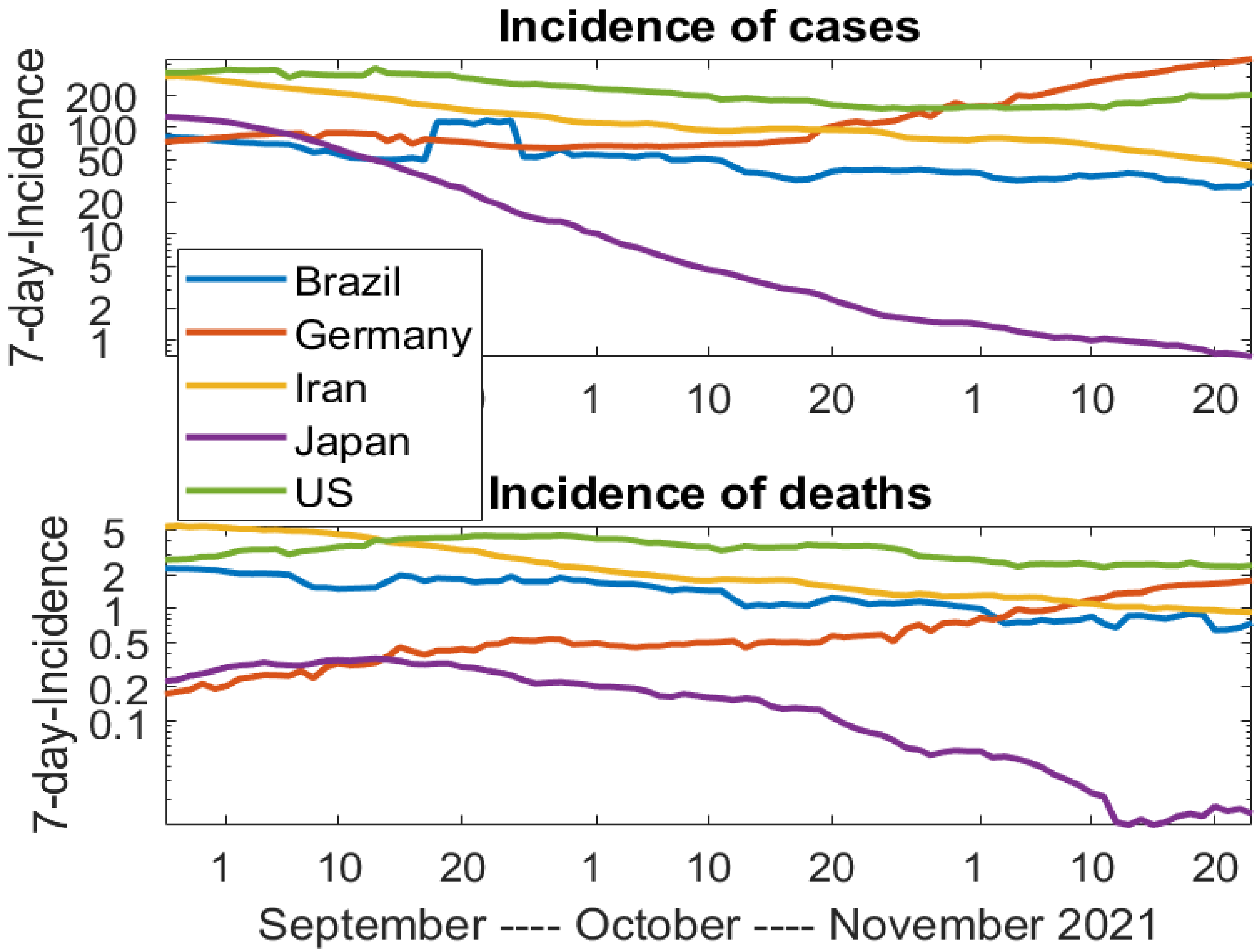
www.intensivregister.de managed by two former Greifswald biomath students

most accurate (but not perfect) data in Germany.

This parameter directly reflects the overload of the health system.

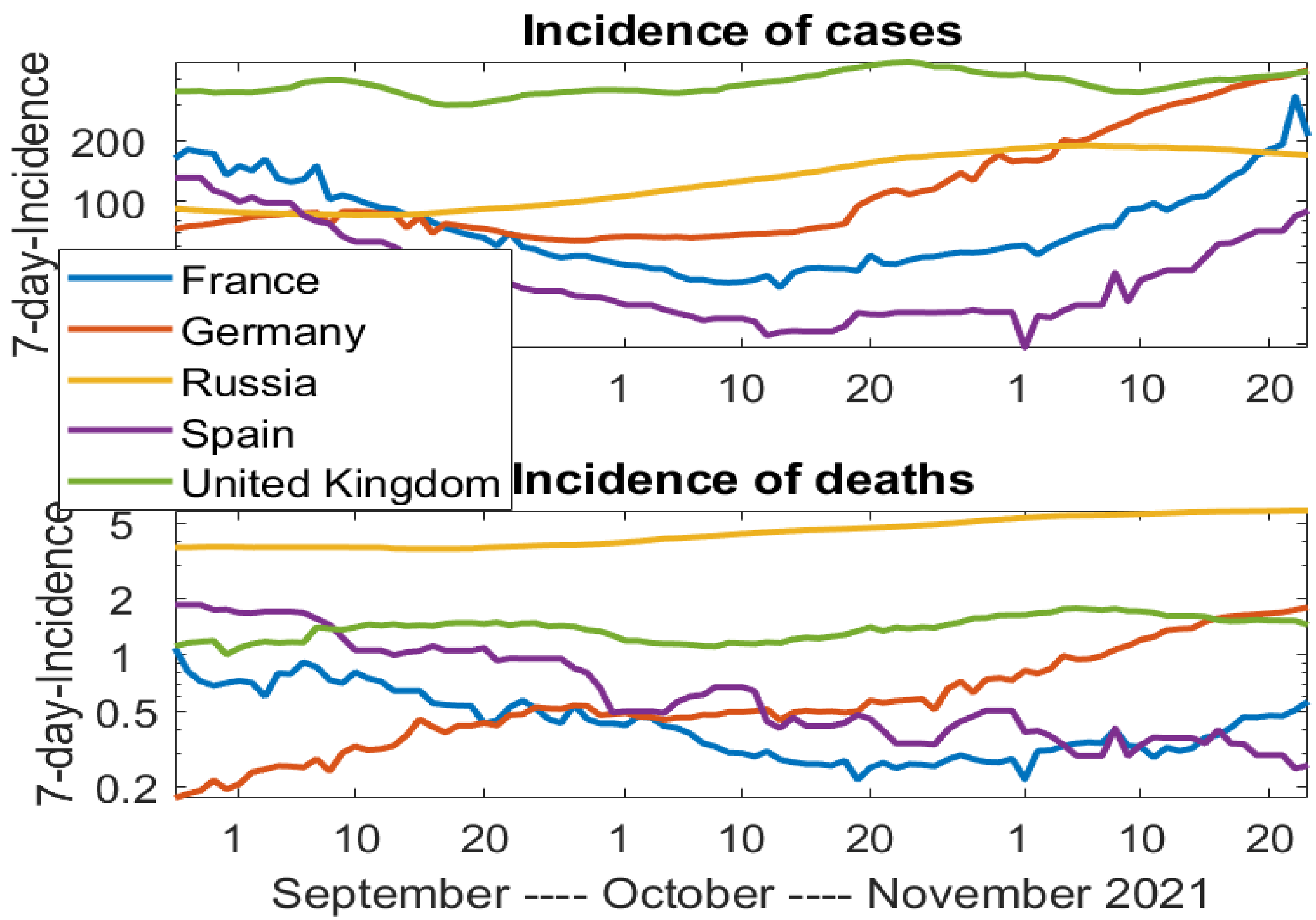
Problems: guest patients, small numbers for small regions

2.2 Comparison of parameters of countries



Japan: zero Covid

Germany:
more cases as USA
and almost as many
deaths
(21 Nov 2021)



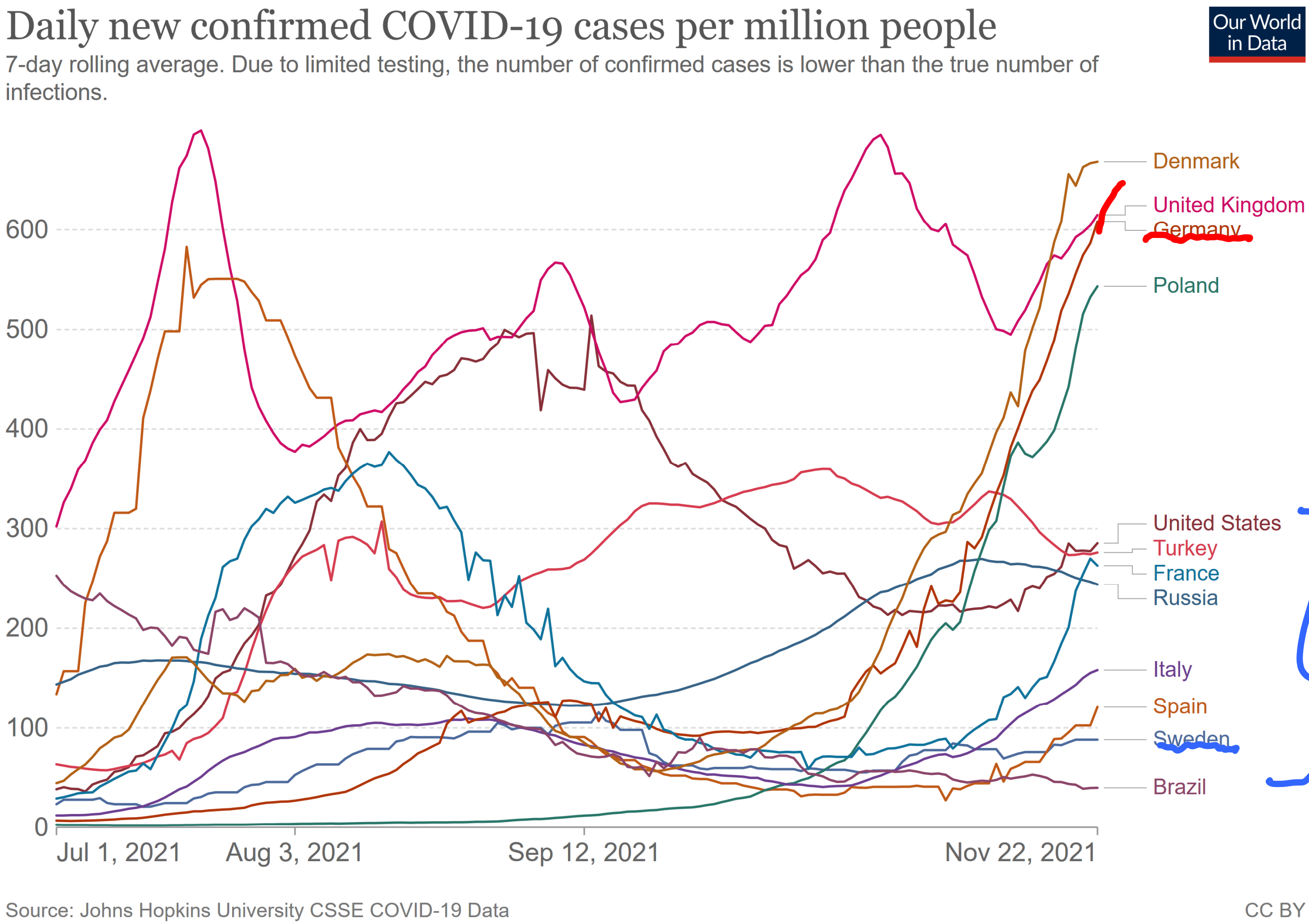
Large European countries:

Germany has most cases, together with UK now more deaths than UK.

Russia had many deaths (20-25% of usual death rate) for several months

France and Spain keep deaths low

Western Europe Cases



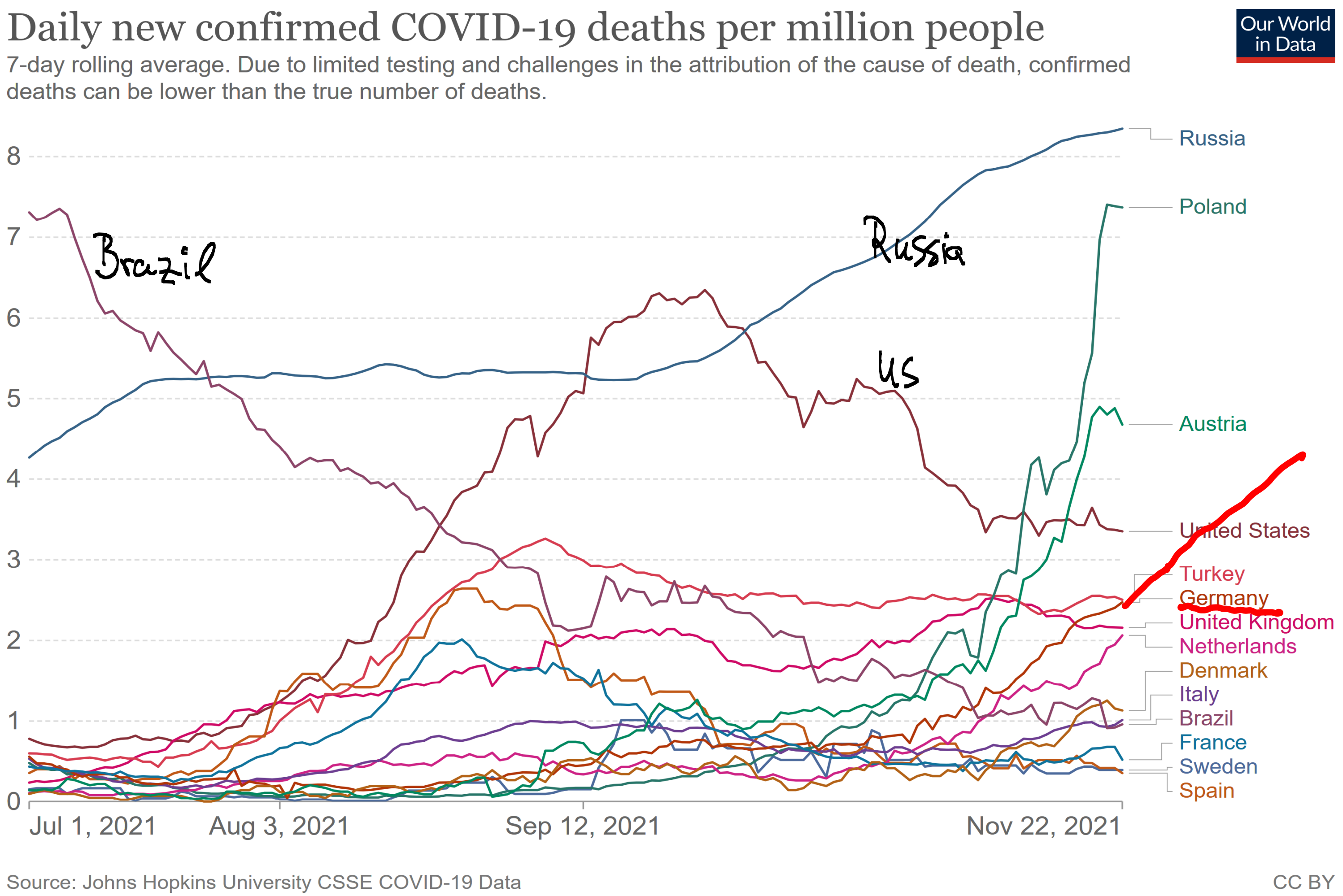
only Denmark (and Austria, Netherlands, Belgium,) have more cases than Germany

incidence smaller 200

(22 Nov 2021)

Western Europe Deaths

(Ukraine: very bad)



Russia + Poland many deaths
Austria too

Germany is next with strong growth

Netherlands, Denmark less deaths but more cases than Germany

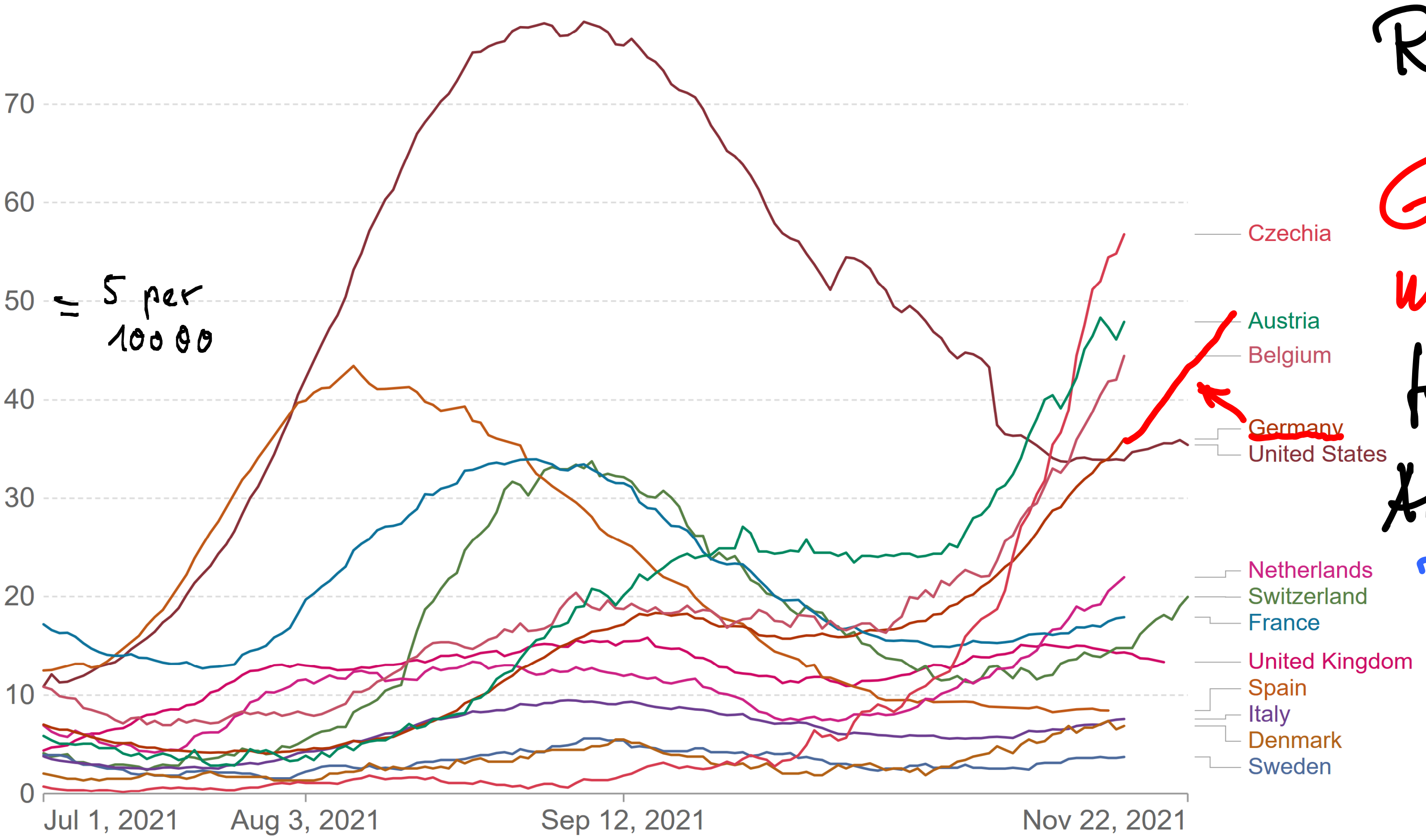
Spain, France, Sweden, Italy: few deaths

Western Europe ICU patients

Number of COVID-19 patients in intensive care (ICU) per million people

Our World in Data

(no data from Russia + Ukraine)



≈ 5 per 10000

Germany has most patients, together with Austria, Belgium

all less than 2 patients per 100000

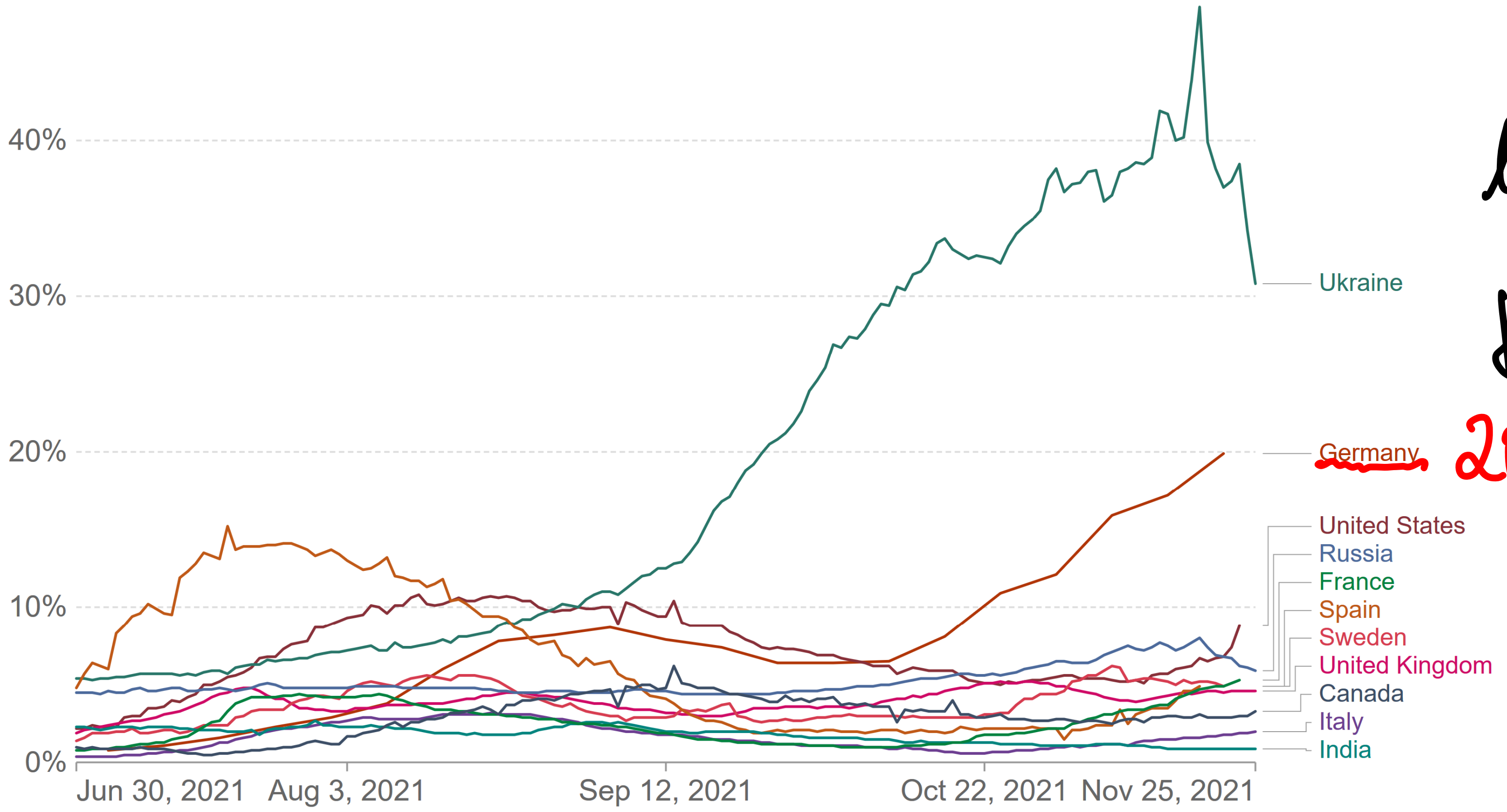
Source: Official data collated by Our World in Data

Western Europe Positive rate

data explorer of Our World in Data. You can try!

The share of daily COVID-19 tests that are positive

7-day rolling average. The number of confirmed cases divided by the number of tests, expressed as a percentage. Tests may refer to the number of tests performed or the number of people tested, depending on which is reported by the particular country.



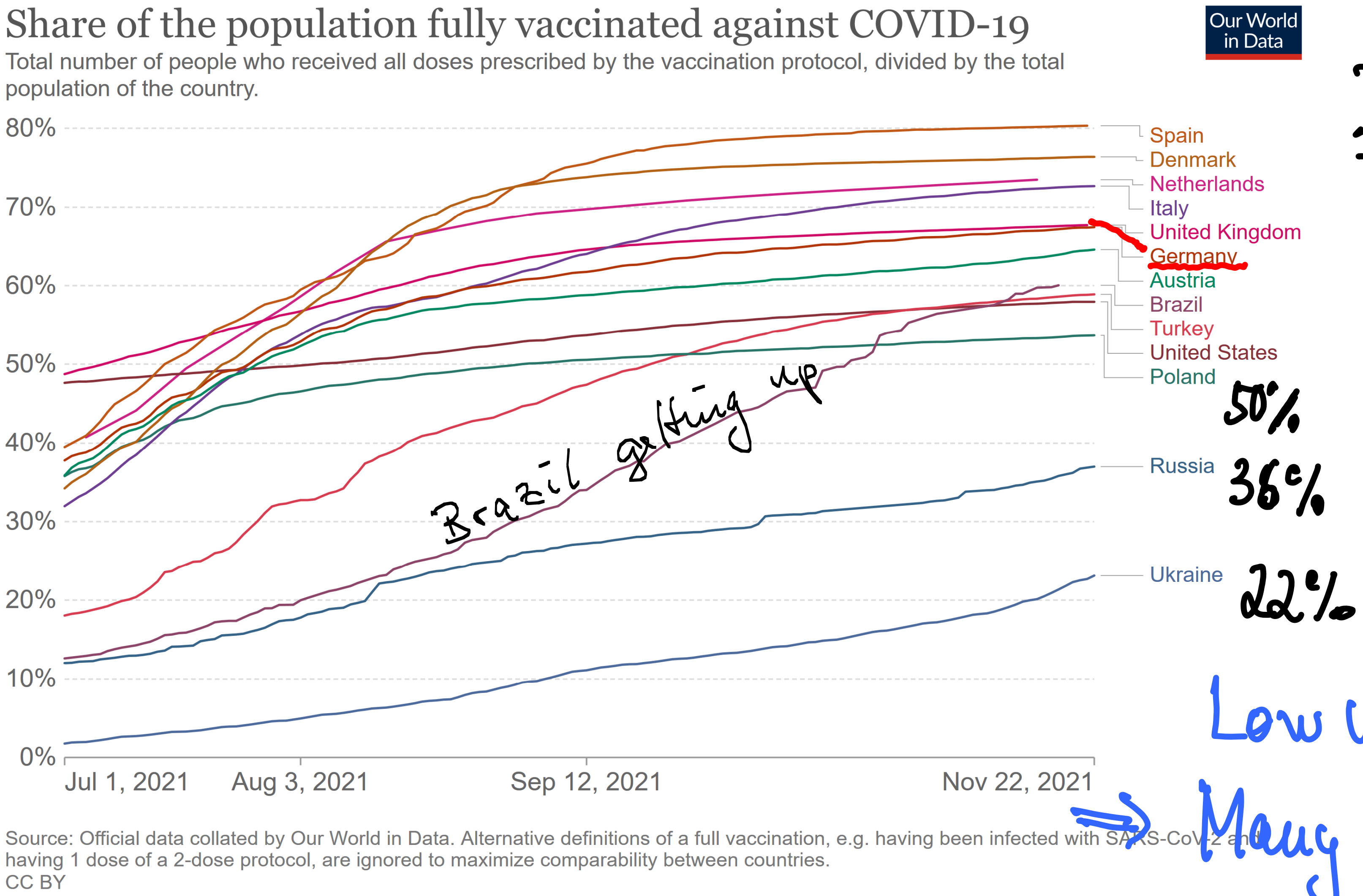
Source: Official data collated by Our World in Data

Only Ukraine has larger positive rate than Germany

20%

all < 10%

Vaccinations



Spain 80%

DK, NL 75%

Italy, France, Sweden 70%

UK, D 67%

Austria 64%

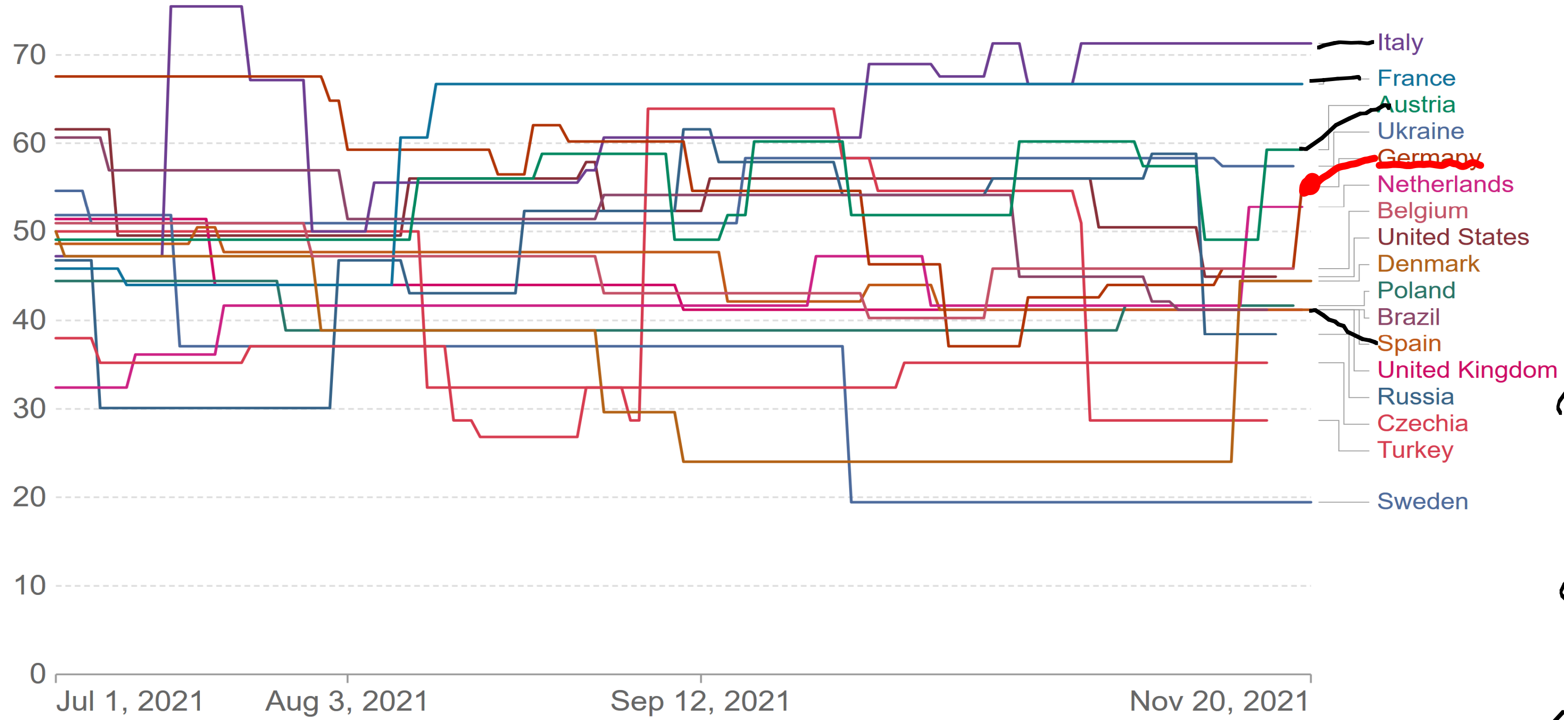
Low vaccination rate

⟹ Many deaths and ICU patients

Government measures – Oxford stringency index

COVID-19: Stringency Index

The stringency index is a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest). If policies vary at the subnational level, the index shows the response level of the strictest subregion.



Italy, France very strict

Spain, UK, Russia, Czechia, Turkey low

Sweden very low

(20 Nov 2021)

Source: Hale, T., Angrist, N., Goldszmidt, R. et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). Nat Hum Behav 5, 529–538 (2021). https://doi.org/10.1038/s41562-021-01079-8

Summary.

High vaccination rate and low positive rate lead to fewer deaths and ICU patients at the same level of cases.

Germany has many cases, a mediocre level of vaccination and a disastrous policy of testing, compared with other countries.

2.3 Germany's hospitalization rate

main parameter, according to Infektionsschutzgesetz and last meeting of Mrs. Merkel with federal prime ministers

Definition: number of hospital admissions with Covid during the last week, divided by population in 100 000

This number is absolutely useless. It shows the lack of competence of German politicians, including the opposition.

- Number of patients is better than number of admissions

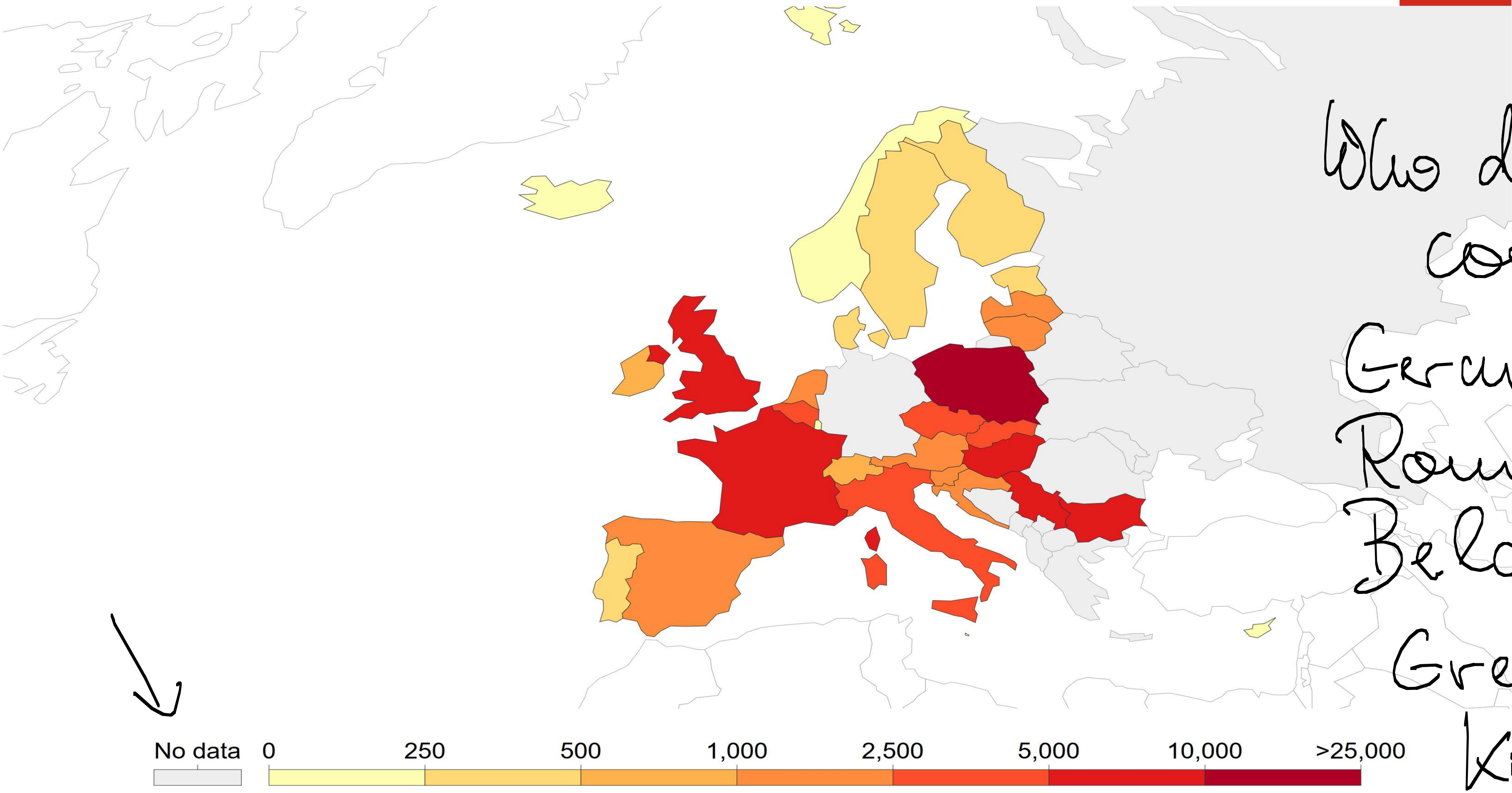
But Germany cannot count number of hospital patients.

In mid-July, hospitals were ordered to report daily admissions. But not the number of dismissals. We know how many went in, but we do not know how many went out and how many remain.

European countries counting hospital patients

Number of COVID-19 patients in hospital

Our World in Data



Who does not count?

Germany

Romania

Belarus

Greece

Kosovo

...

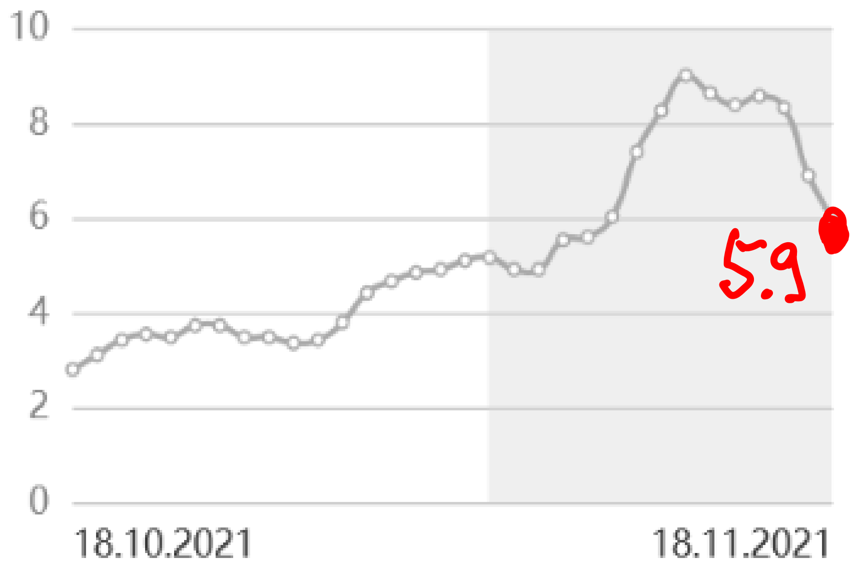
Source: European CDC for EU countries, government sources for other countries – Last updated 28 November 2021, 12:50 (London time)

- Germany has no experience with centralized hospital statistics. Because we started in July 2021.

Hospital administrations are not subordinated to the RKI, in contrast to the Gesundheitsämter.

So the hospitals report admissions with a delay of several days or even weeks.

- The RKI makes no attempt at forecasting missing data. They just sum up what comes in,

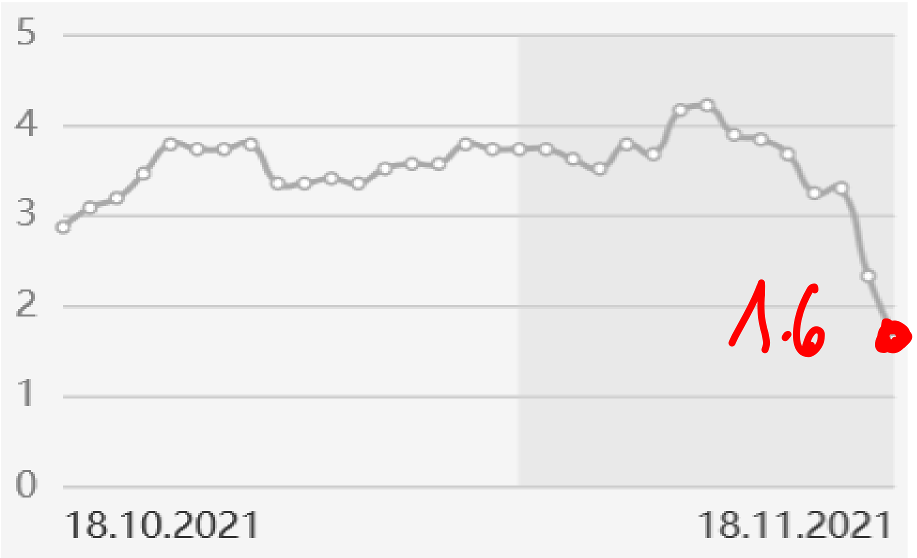


Hospi-rate of MV on 18 Nov
[day of meeting Merkel with PMs]

Hospi-rate of MV of 18 Nov with RKI data from 25 Nov

9,93 instead of 5.9.

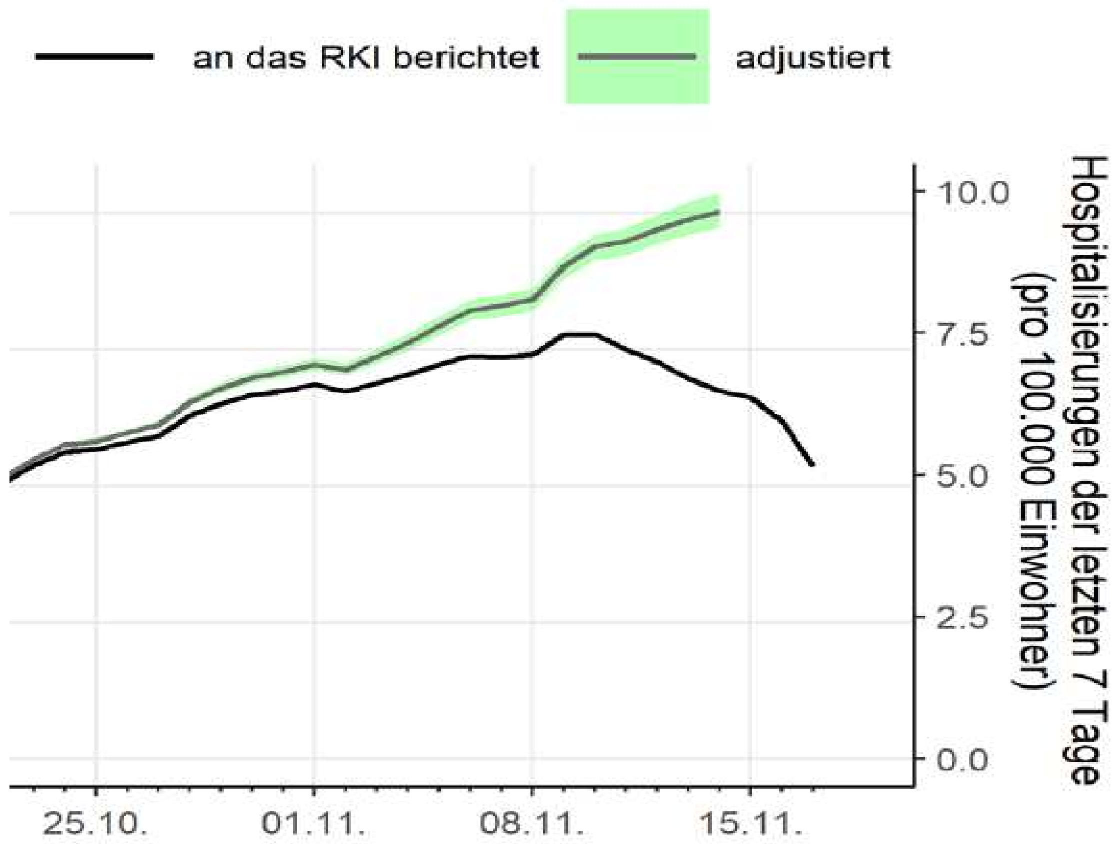
Comparison for Hamburg



Hospitalization rate for Hamburg for 18 Nov. is 1.6 on the same day and 5.15 with the data of 25 Nov.

Source: RKI Covid Trends (graphical overview)

- This problem is well-known since early September. It was discussed in the media (see my webpage) and addressed in the weekly reports of RKI:



on 18 Nov, they offer an adjustment at least until 14 Nov.

(values for Germany)

Nevertheless, Merkel and the Prime Ministers decided to take this parameter, with thresholds 3, 6 and 9, as primary basis for restrictions.

And no one of the six parties in Bundestag suggested a change of this parameter in the new version of Infektionsschutzgesetz.

There are political reasons for the present Covid crisis in Germany.

Why number of ICU patients is better than hospi.-rate

- There are fewer ICUs than hospitals
- Reporting is organized by DIVI, the union of German intensive care physicians
- ICU doctors know how to work with computers
- ICU physicians are present at weekends and nights
- The reporting system runs since April 2020. Various shortcomings were eliminated.
- The ICUs are the real bottleneck in the Covid crisis, due to lack of qualified staff.

3. Mathematical questions

- R values and weekly factors
- estimates of weekly case numbers
- measuring concentration of the pandemic

3.1 Weekly factors instead of R-values

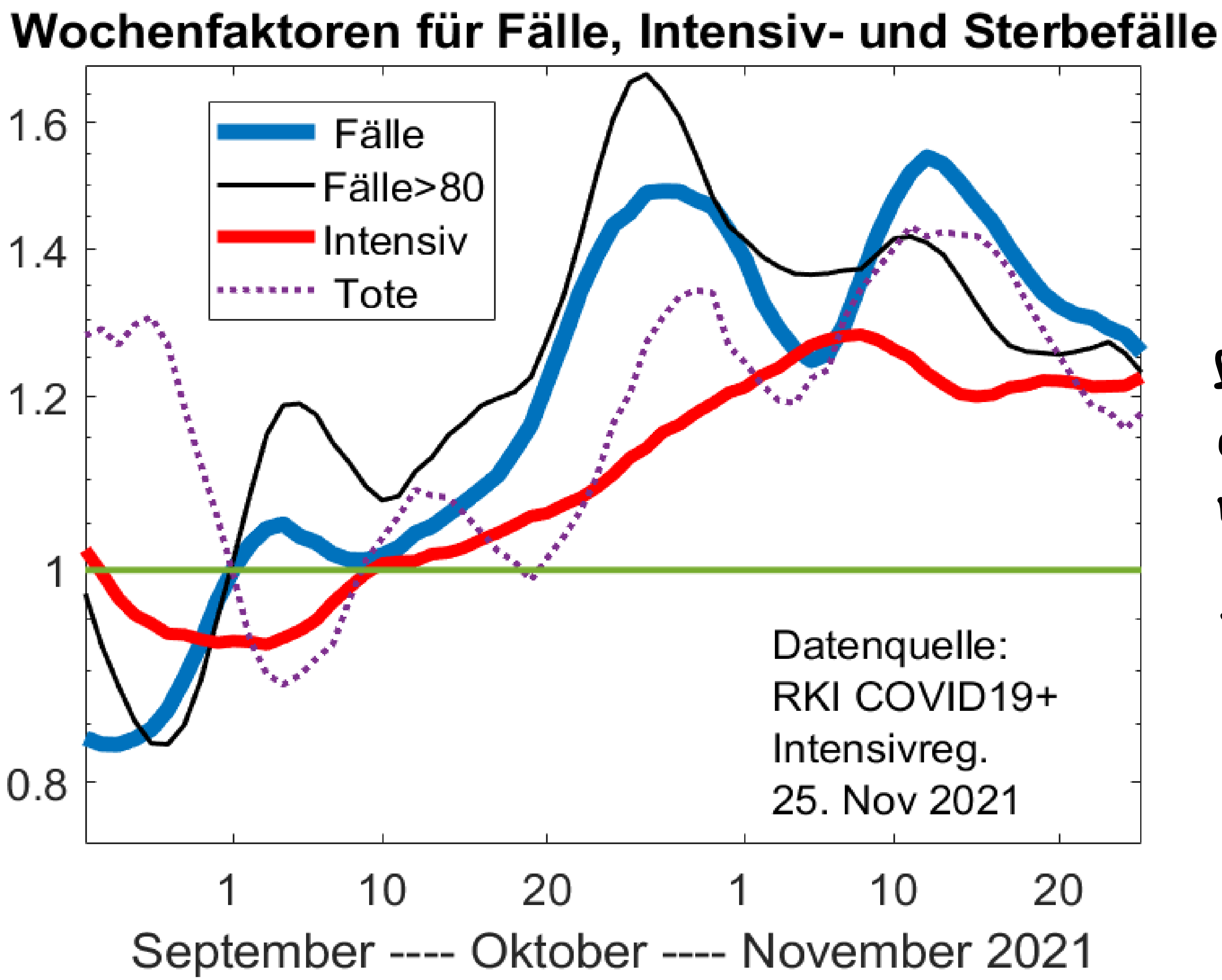
Epidemiologists like the R value: the "average" value of new infections spread by one infected individual. When a pandemic is considered as a branching process, R is the mean of descendants of an individual. Also deterministic models contain the parameter R.

Numerous methods to determine R from data, different in Germany, Sweden, UK, US, Austria etc. I also developed a method. But it turns out that

the simplest proxy of an R value is the weekly factor

case incidence of today divided by case incidence seven days ago.

This factor can be used for cases, deaths, and ICU patients.



At present, all factors are around 1.2.

At the end of September, factors for cases and cases of person >80 years were still < 1.

Factors were smoothed by a rolling geometric average of length 5.

Many media now consider weekly changes, like +20% or −20%.

Why is it important to write factor 1.2 or 0.8 instead?

Because we are on a multiplicative scale.

+20% +20% is not 40%, but 44%. (Compare with stock market.)

Weekly factor R and doubling time T:

$$T = \frac{\log 2}{\log R} \quad \text{since} \quad R^T = 2.$$

Factor $R = 1.2$ corresponds to $T = 3.8$ weeks $= 26.6$ days.

3.2 Estimating weekly case numbers

When cases rise, RKI incidences are always too small. Sometimes 10%, sometimes 50% error. Why?

For a case ω there are two important days

$T = T(\omega)$ day when the case is reported by RKI

$M = M(\omega)$ day when the file for the case is opened in the Gesundheitsamt

"Meldedatum"

Always $M \leq T$

Use probabilistic notation, T and M are 'random variables'.

We want to estimate the number of elements of

$$I = \{t-7 < M \leq t\} \text{ at time } t.$$

RKI reports the cases in I which arrived at day t

$$R = \{t-7 < M \leq T \leq t\}$$

The naive estimator takes all cases which arrived at RKI after $t-7$, until t

$$N = \{t-7 < T \leq t\} \supseteq R \text{ since } M \leq T,$$

Rem. Compared to the naive calculation, RKI neglects the cases with

$$M \leq t-7 < T \leq t \qquad (*)$$

where the file was opened until time $t-7$, but the case arrived at RKI in the last seven days. These are the cases which were delayed over the day $t-7$ by the Gesundheitsamt. Thus slow work of the administration is rewarded by reducing the case number and incidence of the corresponding region. This is absolutely counterproductive.

Compared to the final set I of cases, RKI and naive calculation neglect cases with

$$t-7 < M \leq t < T \qquad (**)$$

which are delayed over time t and have not arrived at RKI yet. They write "some more cases may come in the future".

Idea: since we omit (**), we must include (*) for compensation

Theorem Under some natural stationarity assumptions for daily case numbers and delay by administration, $|N|$ is an unbiased estimator for $|I|$.

Consequently, $|R|$ as estimator for $|I|$ has a negative bias – it systematically underestimates the danger of the pandemic.

Rem. In a situation where cases rise, as in these weeks, the bias of the RKI estimator is even larger, and even the naive estimator underestimates the true case numbers. RKI estimator becomes better when case numbers go down.

Rem. A calculation with historic data of 2020 showed that the L_2-distance to the final case numbers of RKI is four times smaller for the naive estimate than for the RKI estimate.
There are even better estimates than the naive one.

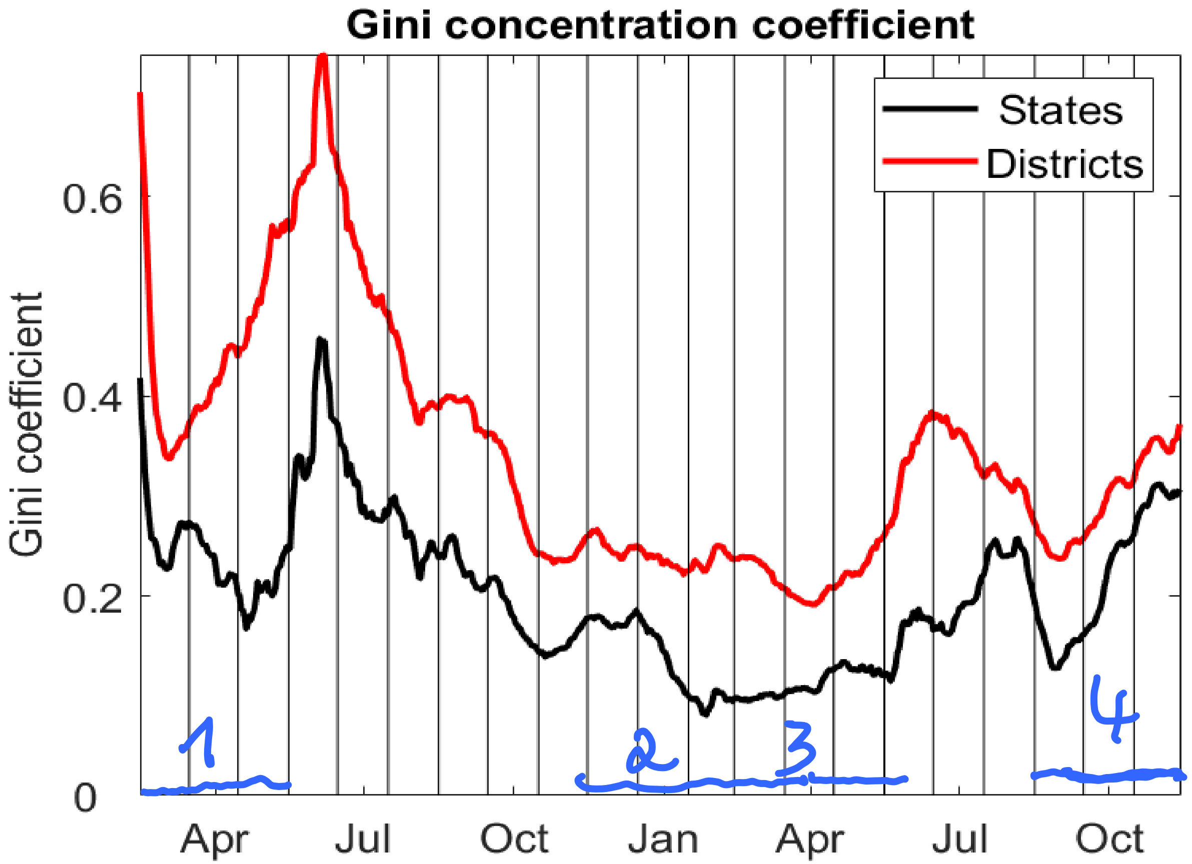
3.3 The concentration of cases

Case incidence is like a <u>mean</u> strength of the pandemic in a region. When we have incidences of several subregions, we would like to define a kind of <u>variance</u> – indicating how much the pandemic distributes uniformly or is concentrated in certain hotspots.

The Gini concentration coefficient, well-known from economy, can be used. G is calculated from the population size q_i and the case numbers p_i for $i=1,\dots,n$. They are standardized so that $\sum p_i = \sum q_i = 1$. Thus G does not depend on overall intensity. We have $G=0$ iff $p_i = q_i$ for all i (full uniformity)

and $G = G_{max} = \frac{n-1}{n}$ iff $p_i = 1$ for one i (full concentration)

Usually the distribution becomes more uniform if the pandemic becomes stronger. However, in the present wave the concentration of hotspots in the South and East grows together with the strength of the pandemic.



G for districts always larger than G for states

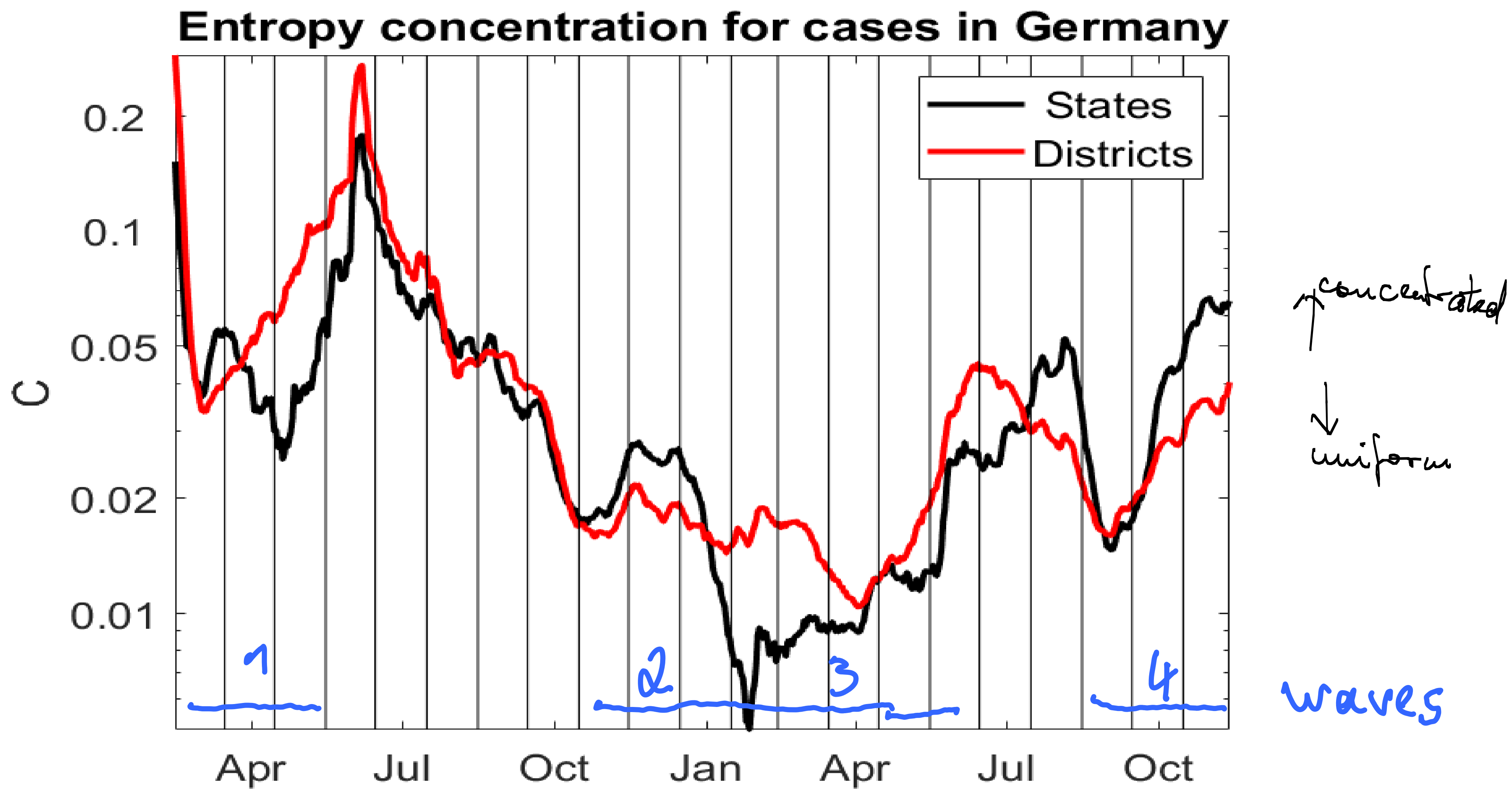
waves

Gini's coefficient depends on the number of subregions.
We have defined an entropy concentration coefficient which for fractal phenomena, like the pandemic, does not depend on the number of subregions. Very simple:

$$C = 1 - \frac{\sum p_i \log p_i}{\sum p_i \log q_i}$$

It has the same properties as Gini's G, and a slightly different scale. (Entropy 2020)

The rising concentration during the present wave shows the need for local measures in Saxonia, Thuringia and Bavaria.


Entropy concentration for cases in Germany
States
Districts
C
0.2
0.1
0.05
0.02
0.01
Apr
Jul
Oct
Jan
Apr
Jul
Oct
1
2
3
4
waves
concentrated
uniform

Conclusion.

- Next weeks will be troublesome.
  Incidences remain high until February.
- Vaccinations are needed but have no immediate effect.
  To avoid lockdown, a huge amount of testing is required.

- The pandemic can destroy our political system
  Only a new political culture can help.

- Everybody can contribute the best at his/her place.