

# **Study on modeling and monitoring the spread of COVID19 virus**

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## **1 Preface**

This document is created purely from personal interest in mathematics and programming. I have no background in medicine nor in social sciences whatsoever, and everything I present may be commonly known for the people having expertise on those fields. Document does not fulfill the requirements of scientific publication, and it is certainly not peer-reviewed, and is evolving over time. Therefore, the information should be considered more or less unreliable, and you should use your own judgement to evaluate if it is accurate or not.

Regardless of it's severity, COVID19 offers a great opportunity to apply mathematics and control theory to societal problems. This work is personal effort to understand 'the truth', the laws behind the societal (control) systems, their responses and their stability. It may also reveal discrepancies between the reality and the executed political actions. Ability to identify them I consider very important during the times we are living.

In Puotila, eastern Helsinki, Finland, March 22, 2020

Marko

## 2 Derivation of spreading coefficient limit of declining infection

In this document I try to develop a model that would help me to understand the essential figures and numbers that we should be monitored and measured in order to distinguish the effective and ineffective measures in limiting the spread of the COVID19 virus.

I start the derivation from the measured reproduction number  $R_0$ . We know that the nature of the growth of the infection is exponential which inherently means the disease is spread by infected persons infecting the uninfected ones over certain period of time.

With COVID19 there is lots of statistics about number of infected persons, daily new cases, deaths and recoveries. Based on these statistics we may derive the estimate of the contamination time during which the infected patient spreads the disease in such a manner that the daily proportional growth equals the monitored reproduction number.

Under assumption that infected persons spread the disease with constant fraction of cases per day, the newly infected persons tomorrow can be expressed as

$$y(n) = Ky(n-1) \quad (2.1)$$

$$K = \frac{y(n)}{y(n-1)} = \frac{y(n) - y(n-1)}{y(n-1)} + 1 \quad (2.2)$$

where  $y(n)$  is the number of infected persons on day  $n$ . Without limiting measures  $K$  is assumed here to be relatively constant.

We may express  $K$  as

$$K = 1 + S \quad (2.3)$$

$$S = \frac{y(n) - y(n-1)}{y(n-1)}, \quad (2.4)$$

where  $S$  is spreading coefficient, the *ratio of daily increase of cases to active cases*. It should be noted that any estimation error that is in fixed proportion to actually confirmed cases is canceled in calculation of  $S$ . Thus we can state that any measure that gives us proportionally relatively stable information will provide us accurate information about  $S$ .

As shown before,  $K_t$  and  $S$  can be measured. So can be the reproduction number  $R_0$ , which for the COVID19 have been estimated to be  $R_0 = 2.06 \dots 2.52$  [1]. These two expansion mechanisms are related, and they should match at least in early phases of epidemic, when deaths, recoveries, countermeasures, and developing immunity do not hinder the spreading. The relation can be expressed as

$$K^{T_c} = 1 + R_0 \quad (2.5)$$

$$T_c = \frac{\ln(1 + R_0)}{\ln(K)}, \quad (2.6)$$

where  $T_c$  is the contamination time, i.e. the effective time during which the patients spread the disease. It can be thought as a time before patient get's so visibly sick that he will be isolated/quarantined from the community and thus does not spread the disease. This time is specific to disease and we may assume here it is relatively constant.

We may now denote the spreading coefficient, measured as the ratio of increase to the active cases, in the beginning of the epidemic as  $S_0$ . Thus

$$T_c = \frac{\ln(1 + R_0)}{\ln(1 + S_0)} \quad (2.7)$$

For present COVID19,  $S_0$  seems to be, with reasonable number of cases, between 0.3 and 0.2, thus we may use  $S_0 = 0.25$  in our example calculations. We may now preform an example calculation for contamination period

$$S_0 = 0.25 \quad (2.8)$$

$$R_0 = 2.5 \quad (2.9)$$

$$T_c = \frac{\ln(1 + R_0)}{\ln(1 + S_0)} = 5, 6. \quad (2.10)$$

Thus the estimate of the contamination time is 5,6 days, and we assume that to remain constant.

Under ongoing epidemic, public authorities and private persons perform measures to reduce  $S$  in order to hinder the spread of the disease. However, as  $S$  and  $R_0$  are connected, we may try to calculate *how low we should reduce  $S$  in order to stop the epidemic under assumption that  $T_T$  does not change*. Stopping the epidemic means  $R_0 < 1$ . We may now calculate the limit  $S_l$  that should result in declining numbers of active patients.

$$(1 + S_l)^{T_c} < 2 \quad (2.11)$$

$$S_l < 2^{\frac{\ln(1+S_0)}{\ln(1+R_0)}} - 1. \quad (2.12)$$

With the given values for current COVID19 outbreak  $S_l < 0.13$ .

In Table 2.1 the obtained values under various assumptions are presented. These values reveal that with given parameter spread there is no *practical* difference in contamination time, it lies between 3,7 to 6,2 days. This means practically two days difference, easily masked by individual variation and real life uncertainties. Furthermore we may quite certainly say there is no chance of epidemic to stop with spreading factors larger than 0,2. Assuming 0.15 might be wishful thinking but may work, and 0.1 should be quite safe.

As the global data for the cases have been collected and made generally available it is possible to evaluate the theory by comparing it to existing data. That comparison well be presented in Chapter 3.

## 2.1 Parameter estimation with measured data

On March 23 friend of mine, Teemu Lehtimäki suggested that the measured relative growth i.e. in Sweden and the trend of measured cases do not support the

Table 2.1: Spreading coefficient limit value under various assumptions on reproduction number  $R_0$  and initial spreading coefficient  $S_0$

$R_0$	$S_0$	$T_c$	$S_l$
2	0.25	4,9	0.15
2	0.3	4,2	0.18
2	0.4	3,7	0.21
2.5	0.25	5.6	0.13
2.5	0.3	4.8	0.16
2.5	0.4	4.2	0.18
3	0.25	6.2	0.11
3	0.3	5.3	0.14
3	0.4	4.6	0.18

$R_0$  parameter value 2,x, but that the correct number could be higher. The arising is, what is the most reliable way to estimate  $T_t$  in the beginning of the epidemic, when the behaviour of the individuals is not affected by the counter measures, but when the cases are relatively scarce. I think one possible method is LMS curve fitting based on measured relative growth and difference of cases  $y(n) - y(n - x)$ . Unfortunately I have some work to do, so I leave derivation of this for later dates.

### **3 Observations and analyses**

To evaluate the validity of the above theory, I have developed and used analysis software available [https://github.com/mkosunen/Covid19\\_SydeKick](https://github.com/mkosunen/Covid19_SydeKick). Software fetches the data automatically from Johns Hopkins database and plots the relative growth and the number of current cases for chosen countries under interest. Observations of the growth and number of cases will be compared to the presented theory so the theory can be adjusted accordingly, or the root causes / explanations for the anomalies will be developed.



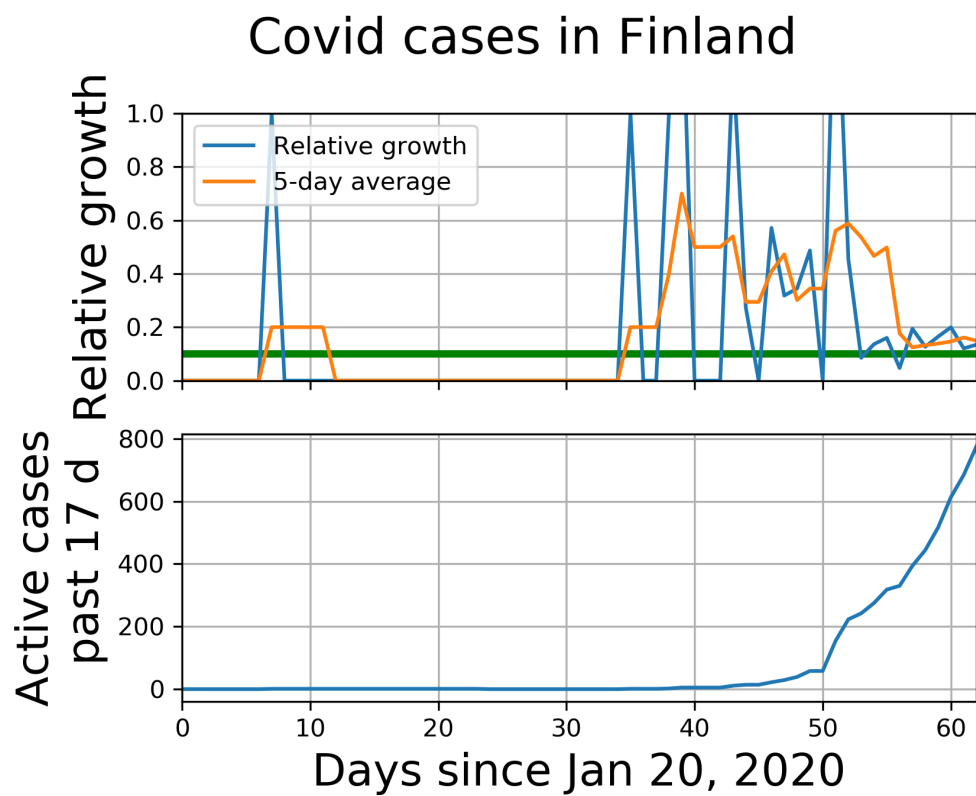


Figure 3.1: Relative growth and number of cases in Finland.

## Covid cases in Sweden

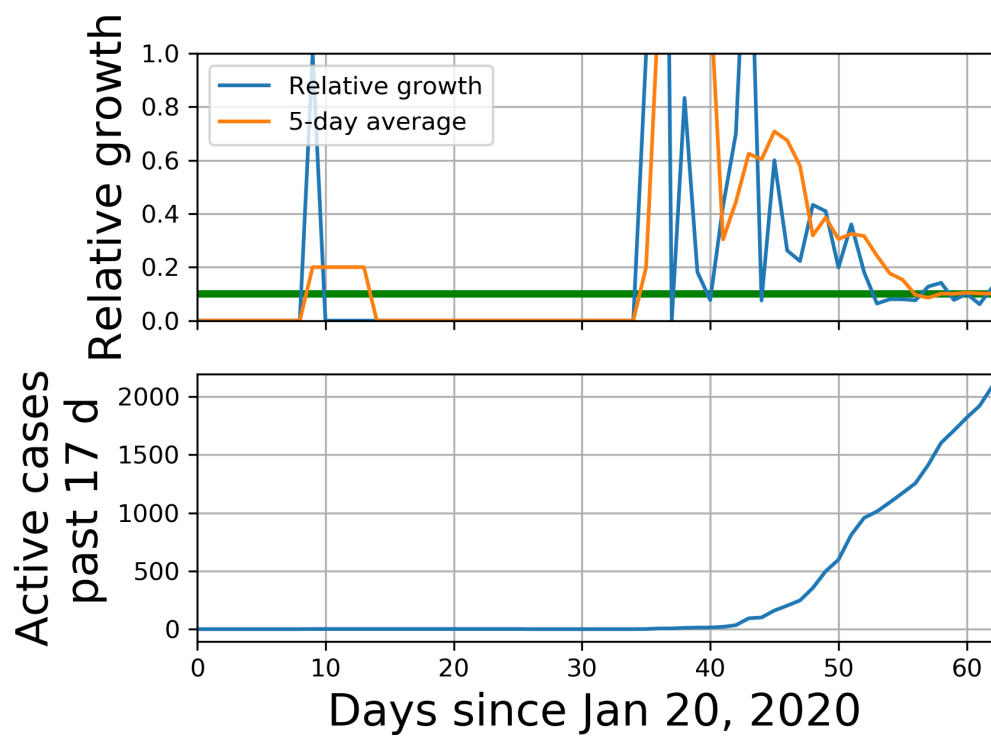


Figure 3.2: Relative growth and number of cases in Sweden.

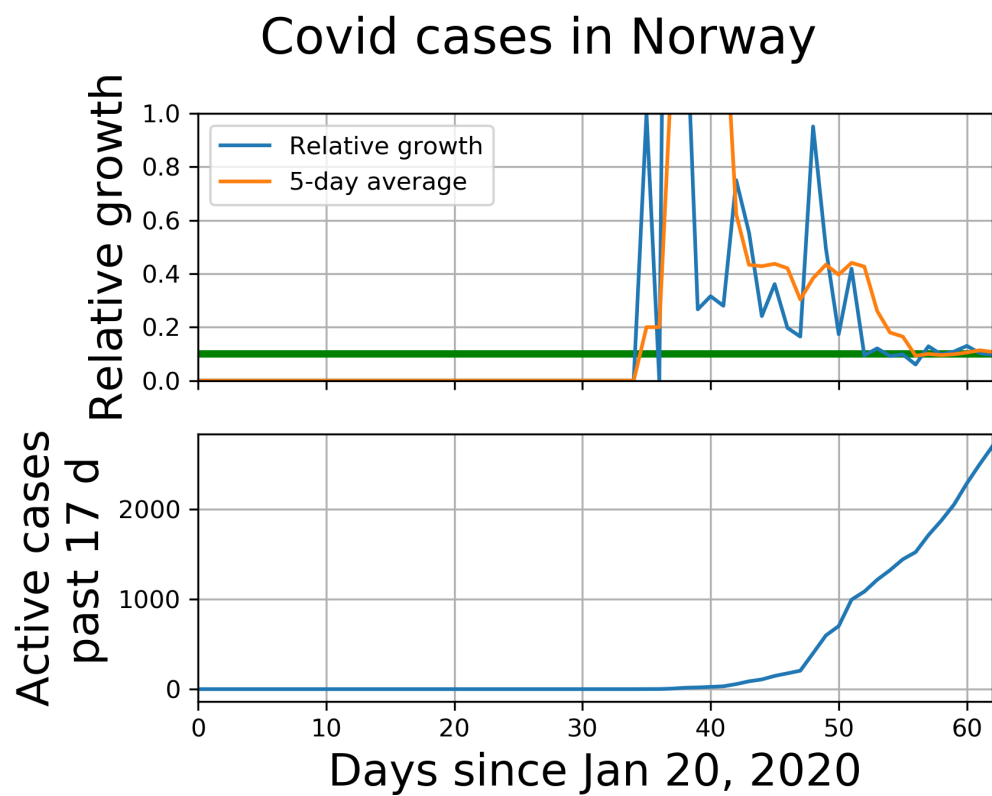


Figure 3.3: Relative growth and number of cases in Norway.

## Covid cases in Denmark

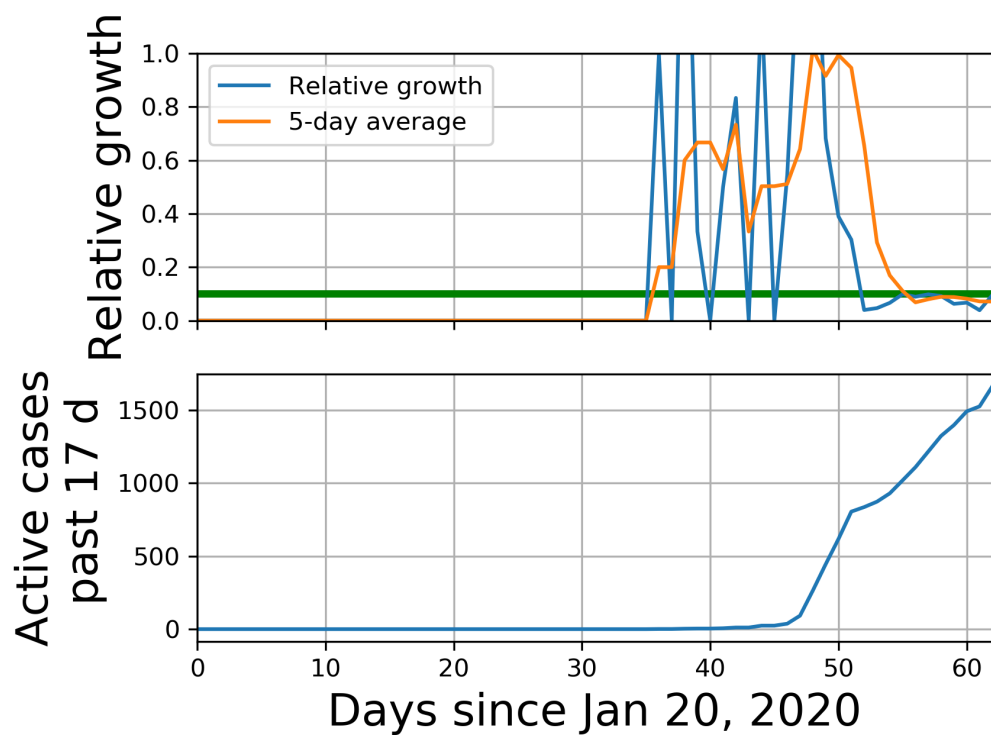


Figure 3.4: Relative growth and number of cases in Denmark.

## Covid cases in Italy

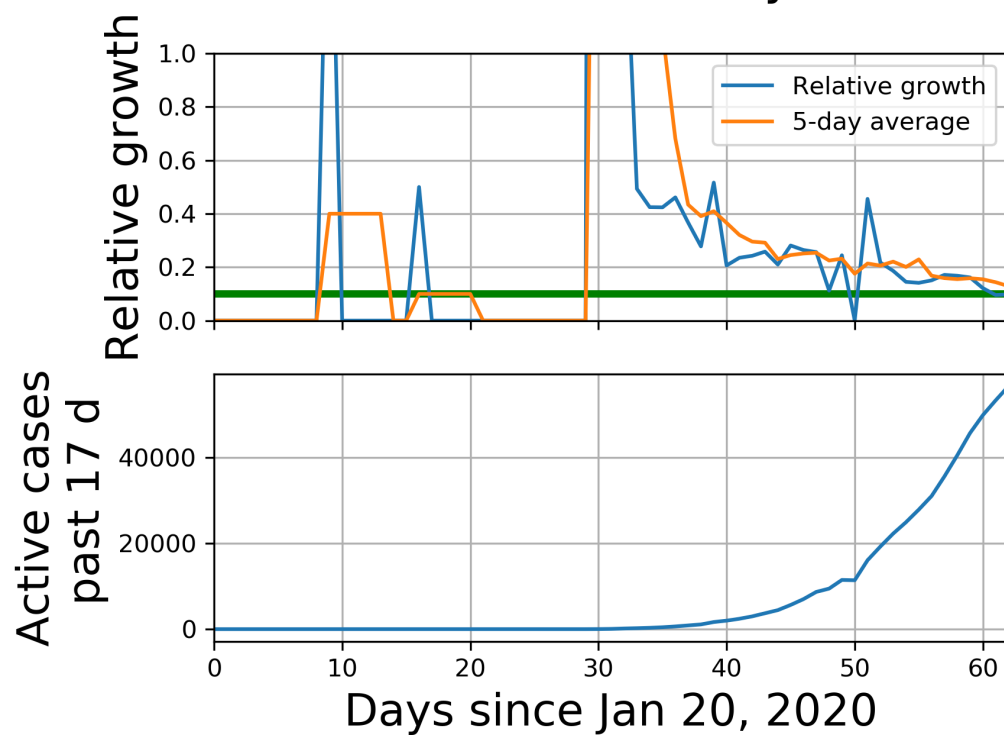


Figure 3.5: Relative growth and number of cases in Italy.

## Covid cases in Germany

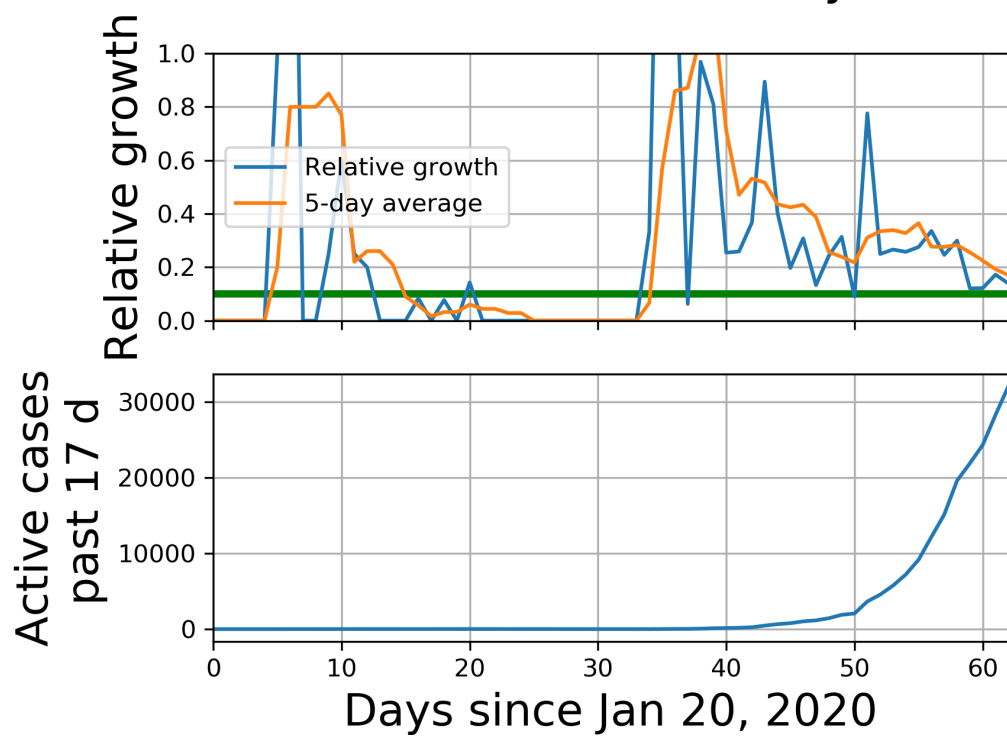


Figure 3.6: Relative growth and number of cases in Germany.

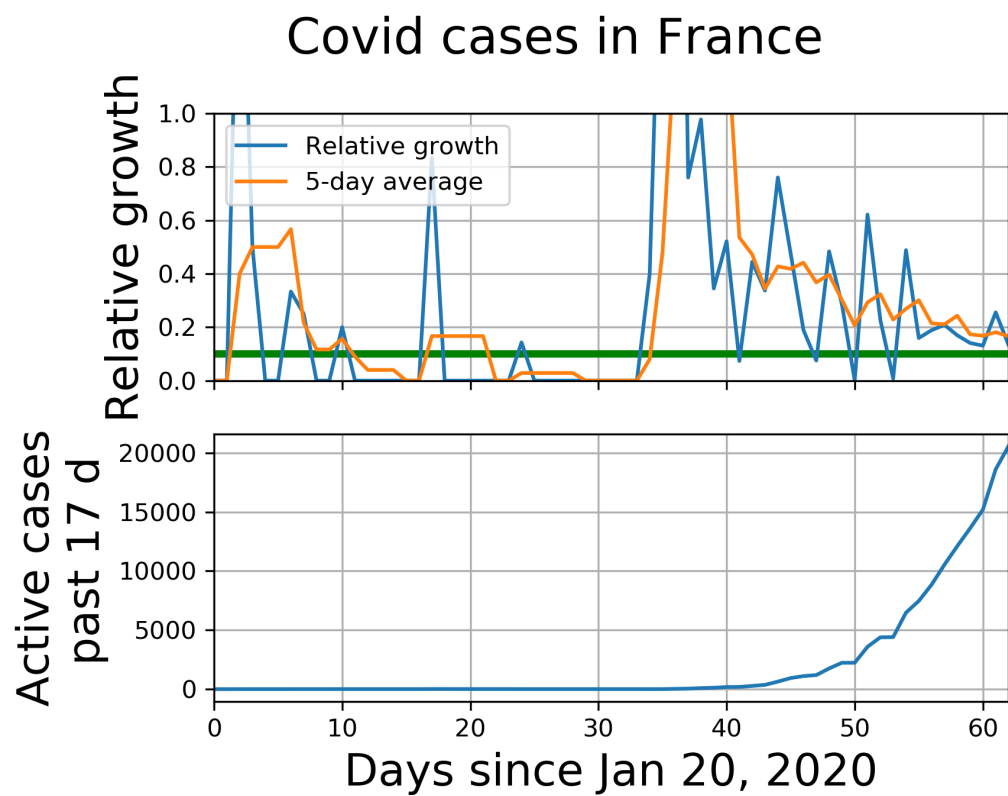


Figure 3.7: Relative growth and number of cases in France.

## Covid cases in Spain

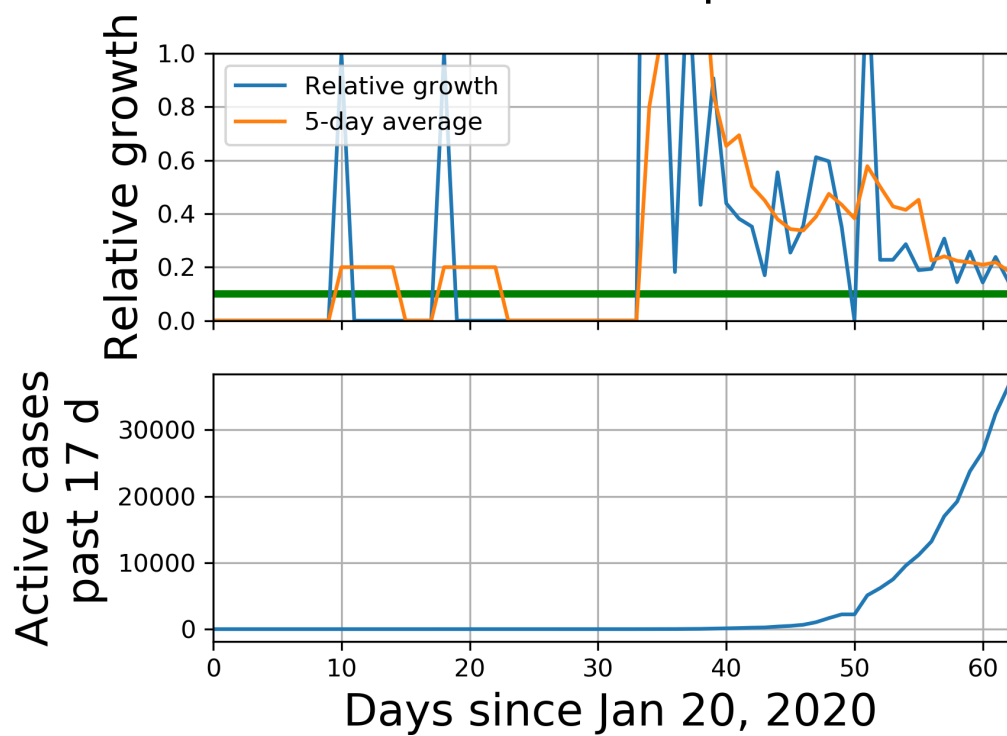


Figure 3.8: Relative growth and number of cases in Spain.



## Covid cases in US

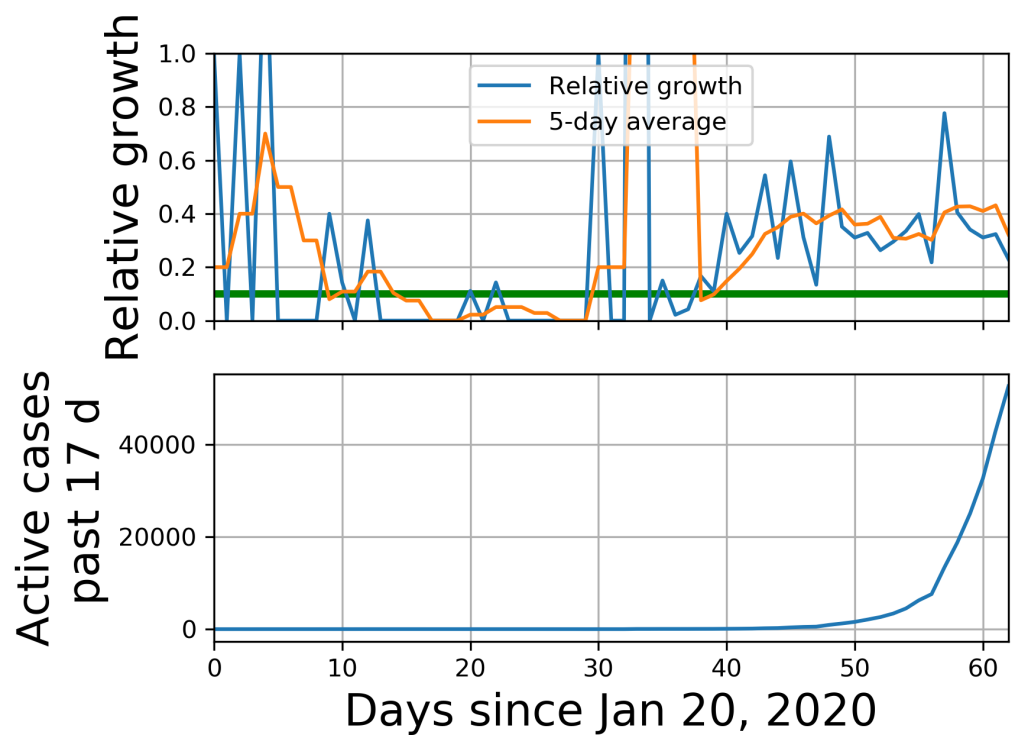


Figure 3.9: Relative growth and number of cases in United States.

South.png

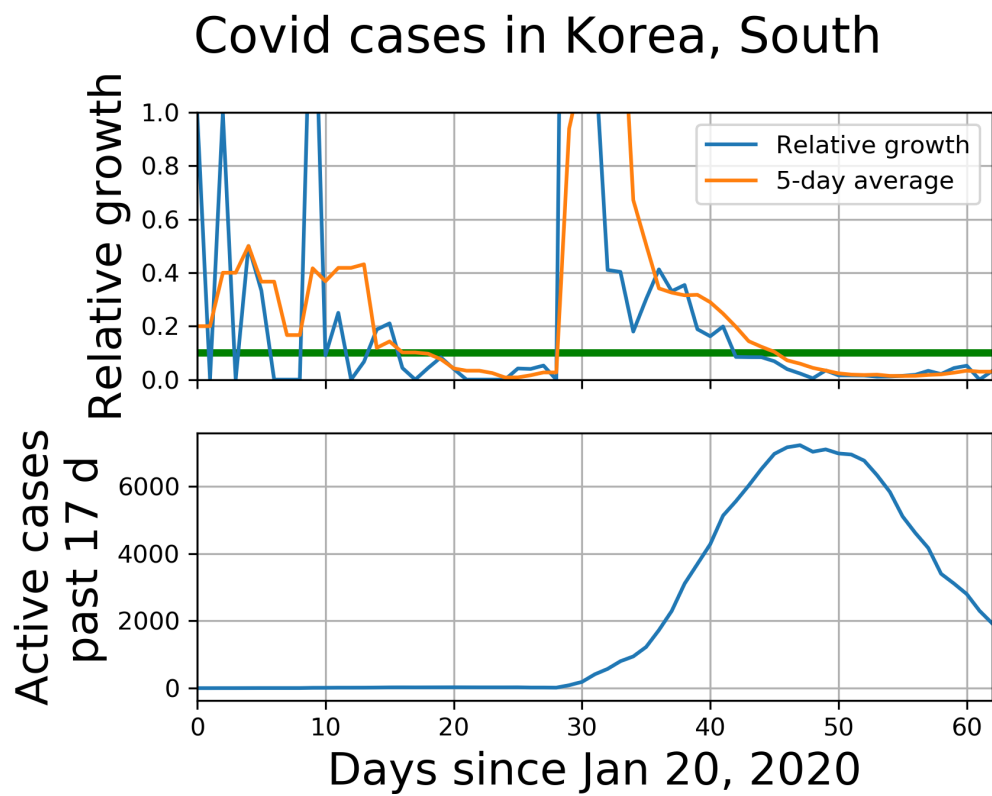


Figure 3.10: Relative growth and number of cases in South Korea.

## Covid cases in China

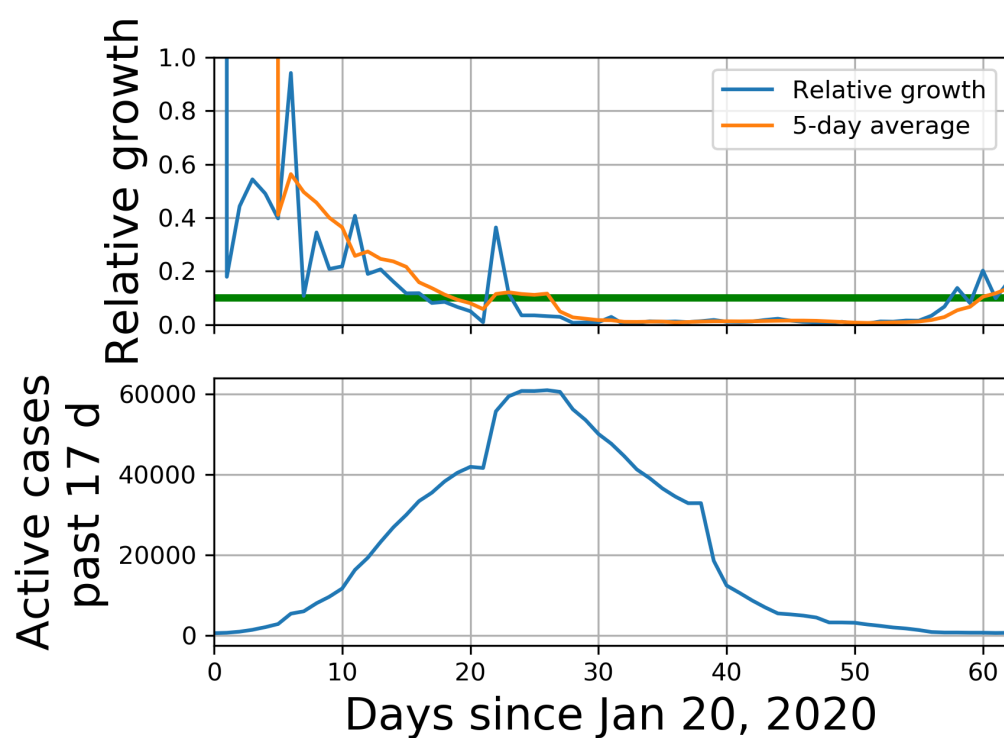


Figure 3.11: Relative growth and number of cases in China.

## Covid cases in selected countries

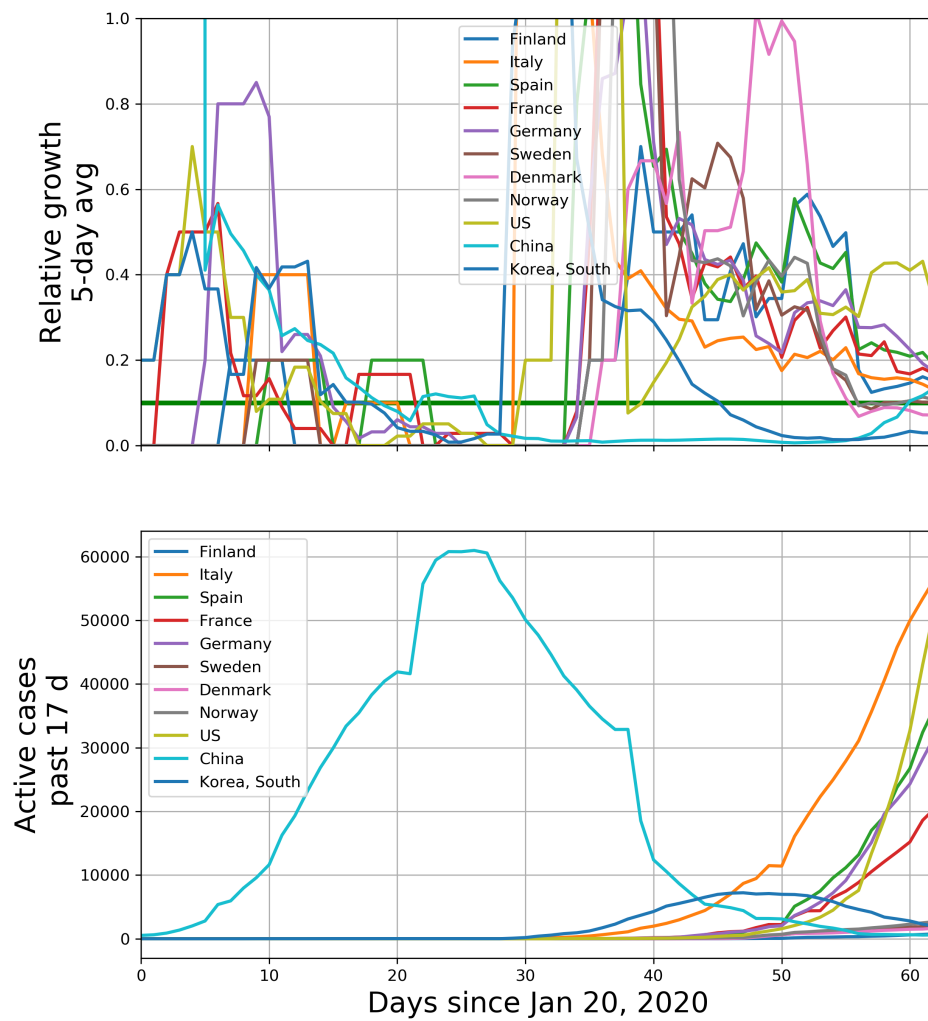


Figure 3.12: Relative growth and number of cases in Selected countries.

## **Bibliography**

- [1] S. Zhang, M. Diao, W. Yu, L. Pei, Z. Lin, and D. Chen, "Estimation of the reproductive number of novel coronavirus (COVID-19) and the probable outbreak size on the Diamond Princess cruise ship: A data-driven analysis," *International Journal of Infectious Diseases*, vol. 93, pp. 201–204, 2020.