

Modeling COVID-19 in Germany

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1 Microstructure Simulation

- Mitigation likely to fail
- Effect of School Opening

2 SIR-Type Models and Parameter Estimation

- Dark Figure
- SIR-Model with Partial Household Structure

Modeling COVID-19 in Germany

Section 1 Microstructure Simulation

Setting

- Agent-based, discrete time, stochastic model
- Sample population with age- and household-structure
- Contact-structure as random graph
- Different contact kernels for household & external contacts

Model

- Population structure based on official census (Poland 2019 & Germany 2014)
- Incubation time: log-normal distributed
- Time to hospitalization: gamma distributed
- Infectious period depends on age and disease progression
- Age-dependent probability for disease progression

	0-40	40-50	50-60	60-70	70-80	80+
asymptomatic	0.6%	0.6%	0.6%	0.6%	0.5%	0.4%
mild	84.5%	84.2%	82.6%	78.7%	71.0%	59.2%
severe (Hosp.)	14.5%	14.4%	14.1%	13.4%	12.1%	10.1%
critical (IC)	0.4%	0.8%	2.7%	7.3%	16.3%	30.2%

- Lethality 49% for critical cases

Contact structure

Inside households:

- Clique structure within households
- Infection probability scales as $1 - \exp(-T/L)$
 T infectious time
 $L + 1$ households size

Outside households:

- Secondary infections: Poisson distributed
Average $R^* = cT \simeq 2.34c$
- R^* acts as **free** parameter
- Estimate from data

Scenarios

- Mitigation possible?



Mitigation and herd immunity strategy for COVID-19 is likely to fail, B. Adamik e.a., medRxiv, 30.03.2020, doi.org/10.1101/2020.03.25.20043109

- Effect of school openings



MOCOS COVID-19 Studie zu den bevorstehenden Schulöffnungen in Rheinland-Pfalz, W. Bock, J.P. Burgard, T.Götz, Techreport, 22.04.2020

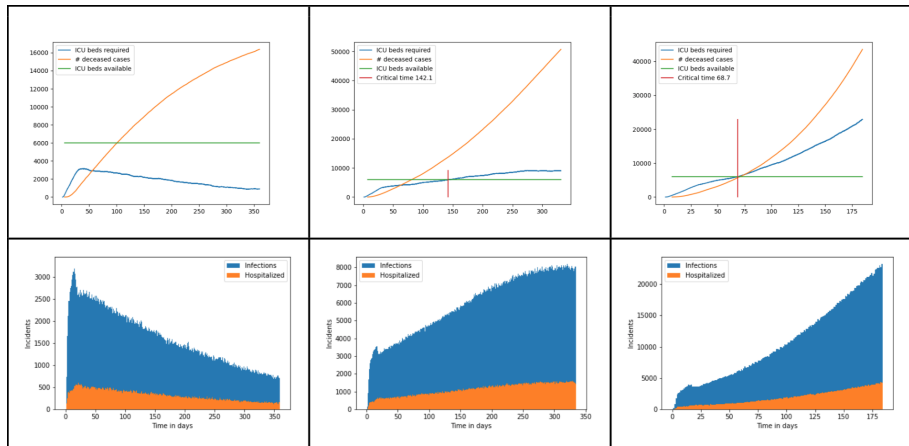
Mitigation likely to fail

- Keep infections **below** capacity of health care system
- Keep infections **above** suppression level
- R^* as **control parameter** (contact ban / curfew)
- Results in short:

Country	from data	mitigation interval	
	R^*_{observed}	R^*_{min}	R^*_{max}
Poland	3.16	0.26	0.37
Germany	3.04	0.37	0.42

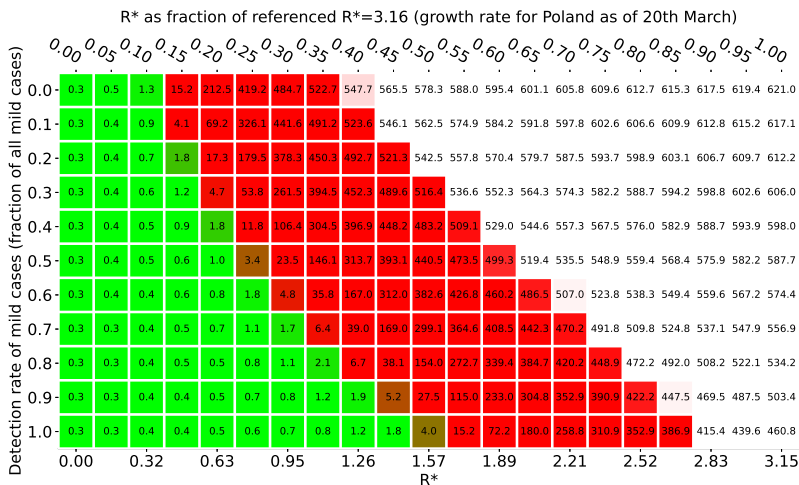
- R^*_{observed} fitted to initial period of epidemics
- **Mitigation likely to fail**, since interval for R^* is too small

Results for Germany



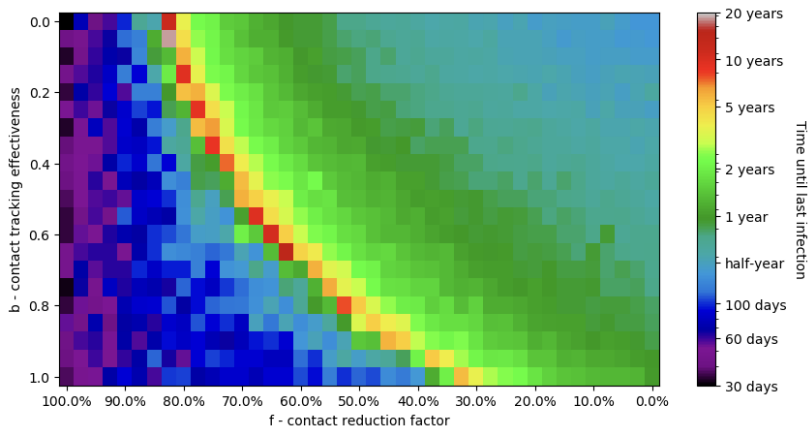
The progress of the epidemic for R^*_{\min} (left), R^*_{\max} (right) and one value in between for Germany. (y-scales different.)

Testing and Social Distancing in Wroclaw



Mean time (in days) until ICU capacity is exceeded.

Tracking: Time till zero new cases



Back-Tracking for all hospitalized and 15% mild cases

$I_0 = 500$, $N = 40.000.000$ (Poland)

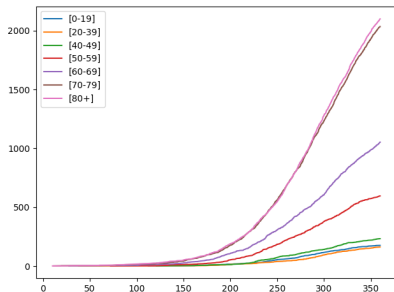
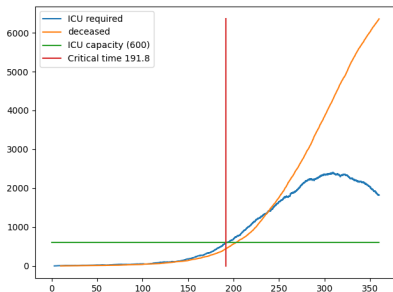
School Opening

- Germany partly opens schools from 27.04 / 04.05. onwards
- Simulation for Rhineland–Palatinate
- Assume certain degree of background immunity ($\sim 1\text{--}2\%$)
- Opening for different grades
- Consider different levels of social distancing at school

School opening – Results

	contacts		immunity level		
	school	external	1%	2%	8%
no opening		11.5%	405	397	358
grade 12	39%	11.5%	99.533	80.155	13.202
grade 10–12	39%	11.5%	100.832	99.258	23.791
grade 12	62%	11.5%	265.897	256.114	204.297
grade 10–12	62%	11.5%	262.206	255.431	203.819
no opening		23.3%	26.041	19.210	3866
grade 12	39%	23.3%	739.579	690.824	353.210
grade 10–12	39%	23.3%	734.271	679.566	378.321
grade 12	62%	23.3%	912.162	870.073	625.195
grade 10–12	62%	23.3%	915.097	866.062	628.582

[Prevalence after 1 year, median of 100 simulation runs]



Scenario: school opening for grade 12, school contacts 39%, external contacts 23%, immunity 8%, ICU capacity 600 beds.

Left: ICU capacity exceed at day 192.

Right: Age distribution of deaths.

Modeling COVID-19 in Germany

Section 2 SIR-Type Models and Parameter Estimation

SIR-Type Models and Parameter Estimation

- ODE-based models
- Partially including household structure
- Computationally cheap, parameter estimation
- Try to identify dark figure



COVID-19 Disease Dynamics in Germany: First Models and Parameter Identification, T. Götz, P. Heidrich, medRxiv, 29.04.2020, doi.org/10.1101/2020.04.23.20076992



A COVID-19 epidemic model integrating direct and fomite transmission as well as household structure, K.P. Wijaya e.a., medRxiv, April 2020

Parameter Estimation and Dark Figure

■ Delay ODE-System

$$\frac{dS}{dt} = -\frac{\beta(t)}{N}SI$$

$$S(t_0) = S_0 := N - E_0 - I_0$$

$$\frac{dE}{dt} = \frac{\beta(t)}{N}SI - \theta E$$

$$E(t_0) = E_0$$

$$\frac{dI}{dt} = \theta E - \gamma [(1 - \mu)I + \mu I(t - \tau)]$$

$$I(s) = I_0(s) \quad \text{for } s \leq t_0$$

$$\frac{dR}{dt} = (1 - \mu) \cdot \gamma I$$

$$R(t_0) = 0$$

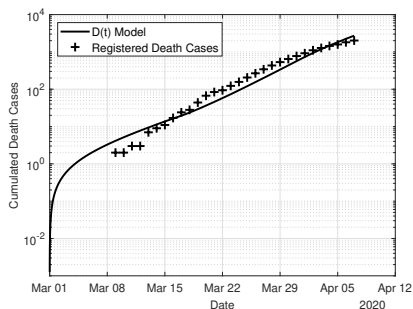
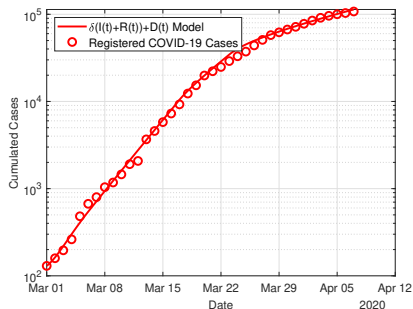
$$\frac{dD}{dt} = \mu \cdot \gamma I(t - \tau)$$

$$D(t_0) = 0$$

■ Parameters $\beta(t), \mu, E_0, I_0, \delta$

δ : Detection rate

Results: Fit until 07.04.2020



Estimated Parameters

β_0	δ	μ	$E_0 + I_0$	β_1	β_2
0.5532	0.202	0.0389	930	0.3578	0.1415

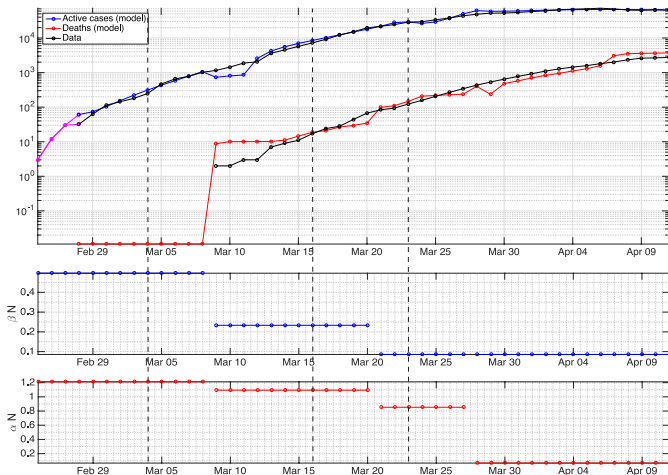
■ Dark figure 20%

■ Lethality 4%


SIR-Model with Partial Household Structure

- Average household size in Germany 2.1 persons, Sri Lanka 3.9
- 100 households form a community
- Higher transmission within community
- Symptomatic and asymptomatic cases
- Symptomatic cases in quarantine
- Almost full detection of symptomatic cases

Results with Households



- Contact ban reduced to contacts to 17%

A black and white photograph of a chalkboard. The words "Any Questions?" are written in a white, cursive, handwritten style. The word "Any" is on the top line, and "Questions?" is on the bottom line. The background of the chalkboard is dark and shows some faint, illegible markings from previous writing.

Any
Questions?