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MOCOS CASE STUDIES FOR ILIGAN CITY, PH

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Abstract. In different media there is an ongoing debate about weakening the social distancing measures. In this techreport we show for the example of the city of Iligan, Philippines, that, in order not to exceed the capacity of the health system, it it crucial to reduce the outer household contacts. Moreover a mitigation strategy is not recommendable, since the social distancing - similarly as in[14] - can not be tuned fine enough. We also simulate how massive testing combined with household contacts can be used in addition to social distancing measures.

MOCOS

This report uses the results and code developed by the MOCOS International research group founded in Wrocław in February 2020. The model description can be found in the appendix.

1. Situation in Iligan City

According to the medical doctors and health managers Iligan City has an approximated capacity of 10 ventilators, which can be considered as the capacity of intensive care units to this moment. In the neighboring province Lanao del Sur of the region ARMM, a growing number of possible incidents of COVID-19 is observed. In times without lockdown a fraction of 30% of citizens of Marawi city and surrounding barangays is commuting daily to Iligan City.

2. Problems in Estimating the Situation

Due to a lack of laboratories it is not to expect, that a massive local testing of possible COVID-19 cases is feasible. This directly influences the reported number of COVID-19 cases, which in Iligan City are with few exceptions based on clinical diagnosis and hence not counted as COVID-19 cases. The lack of this data makes it impossible to predict the exact number of COVID-19 cases. Hence we assume in our simulations that the city of Iligan is virus-free. In the scenarios we start with 10 imported cases. We assume no further infectious persons appear in the city throughout the time of simulation. Due to the number of people commuting to Iligan City every day, this is a conservative estimate.

3. Coming Super-Spreading Events

- On Thursday, 8th of April, 2020 is the start of the Easter celebrations. It is to assume that without a lockdown, many citizens of Iligan City of Christian confessions will gather in churches. This will result in a massive increase of outer household contacts. Such a super-spreading scenario, where for 4 days (Good Friday until Easter Monday) the number of outer household contacts is increased,

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falling back to the value before lockdown contact rate after Easter, is studied will be addressed as possible scenario.

- On 24th of April is the start of Ramadan. During this time many shops in the neighboring region ARMM will be closed. It is to expect that a large amount of citizens of Lanao del Sur will come to Iligan City for shopping during the daytime on a regular basis. Moreover due to the traditional Iftar every day, there will be a large amount of big family gatherings among the Muslim population on a daily basis, which could lead to a increased number of COVID-19 cases during Ramadan in Lanao del Sur and hence via imports of these cases also in Iligan City. In this report however, we will not cover this scenario.

4. Simulated Scenarios

4.1. Finalizing lockdown after 50 days.

Assumptions:

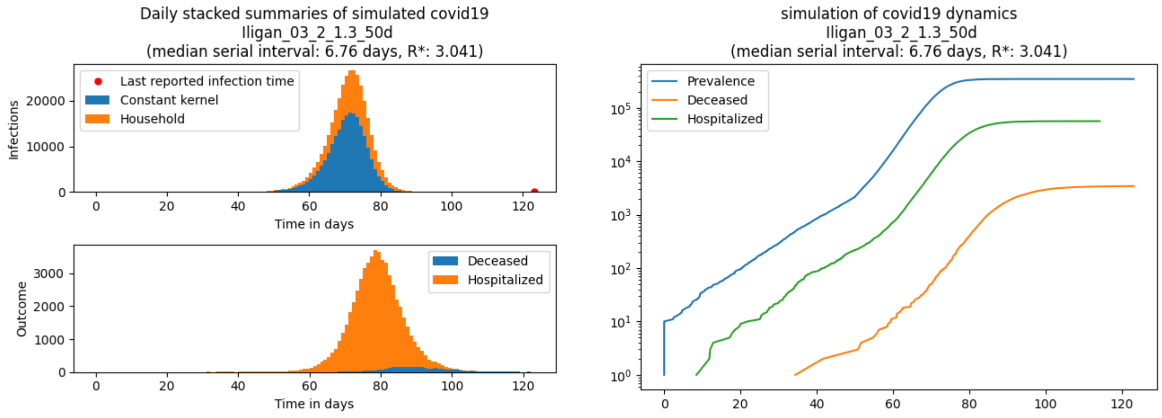
- Iligan City is virus-free during the lockdown
- By the social distancing measures 76,7% of the contacts outside of the households are reduced. This means **instead of 10 people, one person meets between two and three persons outside the household**. Note that also workspace contacts are included in this number.
- At the beginning of the simulation 10 imported infectious persons are inside Iligan city.
- After 50 days, the lockdown ends and people can move freely.
- **In this scenario no imported contacts from other provices are taken into account. This will enhance the speed of the disease spread.**
- **We have not incorporated in our simulations that the exeeding of the ICU threshold leads to a higher mortality rate.**

Results:

After	Prevalence	ICU care	Deceased
20 days	~ 80	6	0
50 days	~ 2400	10	3
80 days	~ 345000	5000	310
120 days	347000	~ 1000	3447

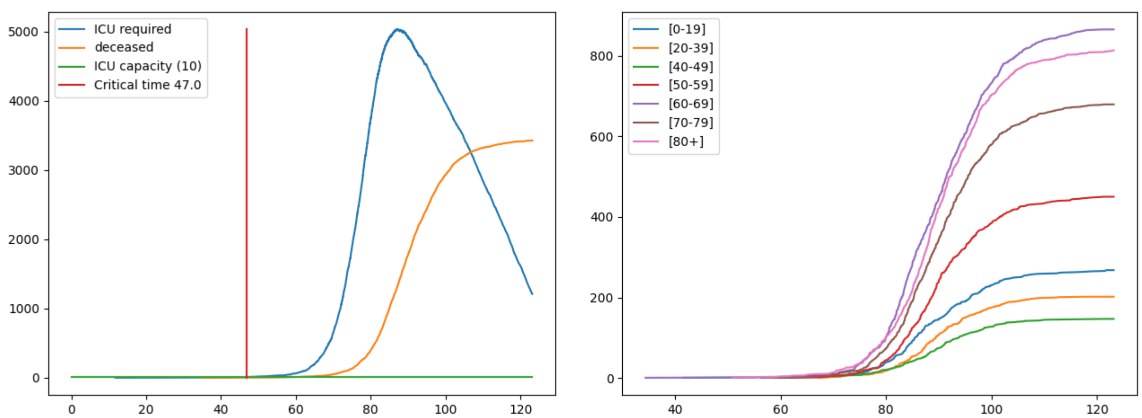
Table 1. Outcome for the scenario 'Finalizing lockdown after 50 days'.

Note: In our simulations the fact that the ICU threshold is exceeded does not affect the number of deceased patients. This assumption very likely is too optimistic.



(A) (B)

FIGURE 1. Incidences and Prevalence for the scenario 'Finalizing lockdown after 50 days'



(A) (B)

FIGURE 2. Sample for the exceeding of the ICU threshold of 10 units and the age spectrum of deceased people for the scenario 'Finalizing lockdown after 50 days'

4.2. **Finalizing lockdown at Good Friday.**

Assumptions:

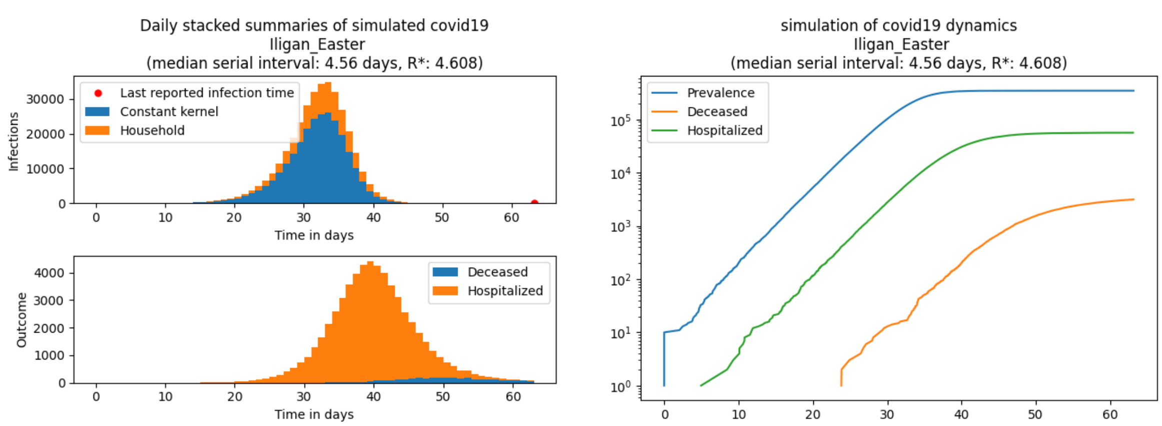
- Iligan City is virus-free during the lockdown
- Lockdown is opened on Good Friday resulting in a increase of the outside contacts to 160% of the pre-lockdown contact rate for 4 days (Easter).
- After Easter the contact rate goes back to pre-lockdown level.
- At the beginning of the simulation 10 imported infectious persons are inside Iligan city.
- **In this scenario no imported contacts from other provices are taken into account. This will enhance the speed of the disease spread.**
- **We have not incorporated in our simulations that the exeeding of the ICU threshold leads to a higher mortality rate.**

Results:

After	Prevalence	ICU care	Deceased
20 days	$\sim$ 80	12	0
50 days	$\sim$ 2400	$\sim$ 5200	1800
60 days	$\sim$ 347000	$\sim$ 3800	3450

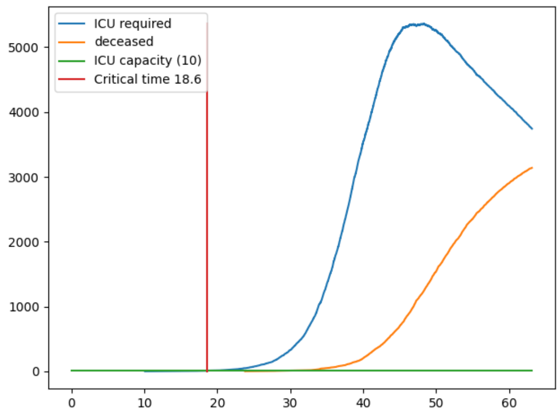
TABLE 2. Outcome for the scenario 'Finalizing lockdown at Good Friday'.

Note: In our simulations the fact that the ICU threshold is exceeded does not affect the number of deceased patients. This assumption very likely is too optimistic.

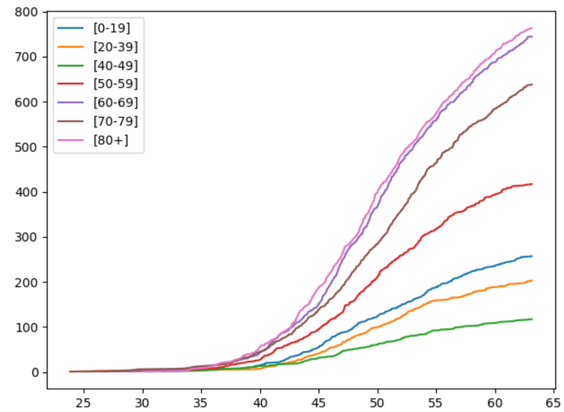


(A) (B)

FIGURE 3. Incidences and Prevalence for the scenario 'Finalizing lockdown at Good Friday'



(A)



(B)

FIGURE 4. Sample for the exceeding of the ICU threshold of 10 units and the age spectrum of deceased people for the scenario 'Finalizing lockdown at Good Friday'

4.3. **Discussion of the two scenarios.** As our simulations show, both scenarios include a large amount of deaths (around 3400) in both scenarios. Please note that at the end of the simulation time there are still people infected and moreover there are in both cases - also at the end of the simulation - more intensive care units needed than the city of Iligan can provide.

- In the scenario 'Finalizing lockdown after 50 days' in around 75 days almost the whole population of Iligan will have been infected, i.e. 25 days the lockdown ended. It is too assume that because of the large amount of hospitalized persons the local health system will collapse. In the scenario 'Finalizing lockdown at Good Friday' after 10 simulations the average time when the ICU threshold is exceeded is around 50 days.
- In the scenario 'Finalizing lockdown at Good Friday' in around 40 days almost the whole population of Iligan will have been infected. It is too assume that because of the large amount of hospitalized persons the local health system will collapse. In the scenario 'Finalizing lockdown at Good Friday' after 10 simulations the average time when the ICU threshold is exceeded is around 19 days.

Note that in both scenarios more persons from the age classes 0-19 and 20-39 die than in the age class 40-49.

5. Quarantine and Social Distancing

Reduction of outer household contacts	92,3 %	84,3 %	76,6 %	68,6 %
Detection rate				
0.0	0	71,4	47,5	38,9
0.1	0	88,8	54,1	43,5
0.2	0	80% 213,5	62,1	48,3
0.3	0	0	87,4	51,7
0.4	0	0	70% 144	67,4
0.5	0	0	10% 51,6	80% 79,1
0.6	0	0	0	40% 110,5
0.7	0	0	0	0
0.8	0	0	0	0
0.9	0	0	0	0
1.0	0	0	0	0

Figure 5. The reduction of social contacts vs. the detection rate q. Only in the case of more than 90% reduction a detection rate of 0 can be allowed.The green fields represent combinations of detection rate and reduction of outer household contacts under which the ICU threshold of 10 beds is not exceeded within 10 independent simulations. The red fields show those combinations for which the ICU threshold is exceeded in all 10 runs. The yellow fields are representing combinations where the ICU threshold was not exceeded in all simulations. The numbers show the average time in days when it exceeds The percentages represent the percentage of runs exceeding the threshold. In the yellow fields the average is just taken over those runs.

Reduction of outer household contacts	92,3 %	84,3 %	76,6 %	68,6 %	61 %	53,3 %	22,3 %
Detection rate							
0.0	0	134,5	83,8	65,5	56,8	50,6	35,6
0.1	0	201,8	98,4	74,0	60	53,4	39
0.2	0	0	126,8	83,3	68,3	57,6	41,7
0.3	0	0	186,1	99,8	75	62	42,9
0.4	0	0	0	133,8	88,8	71,3	45,2
0.5	0	0	0	80% 197,9	110,5	80,6	48
0.6	0	0	0	0	144,3	100,2	50,3
0.7	0	0	0	0	20% 309,6	156,5	52,7
0.8	0	0	0	0	0	90% 263,1	59,4
0.9	0	0	0	0	0	0	69,3
1.0	0	0	0	0	0	0	89,5

Figure 6. The same setting as in Figure 5. Here the ICU threshold is 150 beds

5.1. **Discussion.** The figures show how the detection rate in massive testing and social distancing, i.e. the reduction of the outer household contacts influences the dynamics of the epidemic. The green fields represent combinations of detection rate and reduction of outer household contacts under which the ICU threshold is not exceeded within 10 independent simulations. The red fields show those combinations for which the ICU threshold is exceeded in all 10 runs. The yellow fields are representing combinations where the ICU threshold was not exceeded in all simulations. The numbers show the average time in days when this happens. The percentages represent the percentage of runs exceeded the threshold. In the yellow fields the average is just taken over those runs.
A successful mitigation strategy, i.e. the controlled building of a herd immunity is just possible in the yellow fields. Here, successful means that even at the peak of the outbreak the epidemic stays below the capacity threshold of intensive care units. The other combinations lead either to a suppression or a supercritical epidemic. Note also that the larger the numbers in the fields, the smaller is the prevalence. The capacity threshold for Iligan city was here assumed to be accessible 10 intensive care units. To compare we provide also a scenario for 150 ICUs. As described in the scenario section, we assumed the initial number of infected to be $N_0 = 10$.

Since empirical case data for Iligan city is absent, we made a conservative estimate for the R^*_{free} without social distancing measures. In a previous paper[14] we predicted $R^*_{free} = 3.04$ for Germany and $R^*_{free} = 3.16$ for Poland. Similar sizes, i.e. $R^*_{free} \sim 3$ can be found also in other countries. For cities, we obtained for Berlin $R^*_{free} = 3.88$. It is to expect, that also the actual R^*_{free} for Iligan City is higher than 3, hence our estimate can be seen as conservative.

5.2. **Only Social Distancing Measures.** The results in the previous section are just possible in the presence of enough testing. If a massive testing is not possible, due to the lack of laboratories or other capacities, social distancing is a possible non pharmaceutical measure. We assume again the $R^*_{free} = 3$ in the case where we have no social distancing, which is a reasonable value as described before. In this subsection, we assume no quarantine measures. In particular we assume that neither the mild nor the severe cases are detected.

	Observed data	**Intervals of $\mathbf{R}^*$**	
Entity	**Assumed $\mathbf{R}^*_{\mathbf{free}}$**	$\mathbf{R}_{\mathbf{min}}$	$\mathbf{R}_{\mathbf{max}}$
Iligan	3	0.12	0.23

TABLE 3. Intervals of $R_{min} \leq R^* \leq R_{max}$ for a possible successful overcritical mitigation.

Table 2 shows the intervals of $R_{min} \leq R^* \leq R_{max}$ which contain the interval in which a successful overcritical mitigation is possible for the example of the city of Iligan. In other words R_{max} and R_{min} are upper and lower bounds for a successful mitigation. The present value of $R^*_{free} = 3$ was assumed to be 3 in absence of case data . The ICU threshold is again assumed to be 10 units. The upper bound for R^* of those intervals is denoted by R_{max}. This value is transferred into an average per day growth rate of prevalence, as it is reported by most health offices in their daily situation reports. We defined R_{max} as the smallest R^* value for which 10 sample paths surpassed the ICU threshold within 200 days. The critical value R_{min} was defined as the largest $R^* < R_{max}$ for which the daily incidence at day 200 was below 50% of the initial number $N_0 = 10$ of infected . As can be seen from the values in Table 2, the interval for a successful mitigation is below 10% of R^*_{free}.

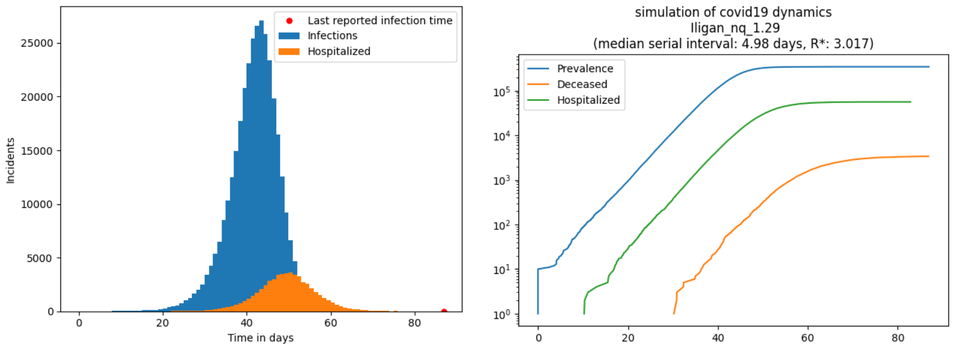


FIGURE 7. Timeline of the relevant observables for the uncontrolled epidemics: an example outcome of the epidemic in Iligan growing at $R^*_{free} = 3$ starting from 10 infected agents; We run a simulation on a randomly sampled population of 342 thousands of agents that fits the demographics (including. age and household structure) of Iligan City. The left figure presents daily incidents: new infections and hospitalization events. The right figure shows a plot with the timeline of the epidemic. More than 95% of the population is predicted to be infected within a 2 months time frame starting from the first 10 infected agents.

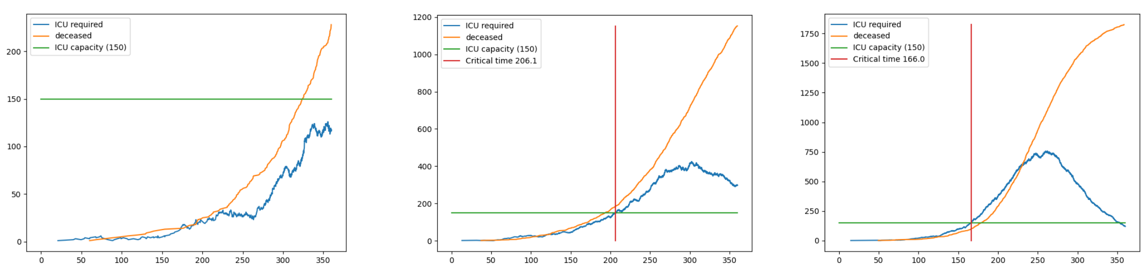


FIGURE 8. The progress of the epidemic for R_{min} (left), R_{max} (right) and one value in between for Iligan City.

6. CONCLUSIONS

(1) Semi-realistic microsimulations for Iligan City, on the basis of our model, give strong indications that there is only a narrow feasible interval of epidemiologically relevant parameters within which a successful mitigation is possible even in the scenario where testing and quarantine measures are invoked. Social distancing measures imposed by state authorities can hardly be fine-tuned enough to hit this critical interval precisely. Furthermore, the herd immunity within these intervals would hence not provide sufficient protection for a second epidemic wave. The main reason for the narrowness of the mitigation interval as well as for the low critical value R_{min} is as in[14] the household structure. Infections within the households for patients with mild progression can hardly be avoided and therefore

a small number of infection links between the households can already make the epidemic overcritical.

(2) In the subcritical domain we observe a strong dependence of time till extinction on the out-reproduction number R^*. We conclude that instead of a mitigation strategy, an extinction strategy implemented by quick, effective and drastic countermeasures similar to those put in action in China is ultimately required to reduce social contacts outside households. **If contact reduction is not kept in force until disease extinction a second epidemic outbreak may result**.[8] Therefore, in order to control the epidemics it is necessary to wait until it gets extinct.

(3) In the two simulated scenarios the ICU threshold was exceeded a short time after the lockdown has ended. In both cases it is to expect that the current health system in Iligan city is going to collapse. Increasing the number of intensive care units increases the time until the ICU threshold is exceeded. Both times could be used to prepare further medical units and staff.

(4) The application of an epidemic management plan based on a flawed strategy of herd immunity may easily lead to an uncontrollable epidemic. We also strongly advise combining social distancing and contact related countermeasures with an extensive testing strategy including individuals with characteristic symptoms but unknown contact history.

Appendix A. Model description

We model spread of COVID-19 with an individual based SIR model. This non-Markov stochastic process incorporates the infection probability of susceptible in contact with infected individuals.

Population structure: Our sample population is based on a synthetic reproduction of the microcensus in Iligan City based on the microcensus data in the Demographic and Health survey 2017[9] and involves age and household composition. We omit here more detailed structures like spatial assignment, gender, profession or comorbidity relevant health status.

Disease progression within patients: The disease progression is modeled according to the present medical knowledge. The incubation time is assumed to follow a lognormal distribution with median 3.92 and variance 5.516 [lognormal parameters: shape=0.497, loc=0.0, scale=3.923]. The age dependence of the probability to be hospitalized or to have severe progression or to have critical progression with requirement for ICU treatment is given in Table 1.

Symptoms	**Age groups**			
	0-40	**40-50**	**50-60**	**60-70**
Asymptomatic	0.006	0.006	0.006	0.006
Mild	0.845	0.842	0.826	0.787
Severe	0.144	0.144	0.141	0.134
Critical	0.004	0.008	0.027	0.073

Table 4. Age dependence of the probability to develop a certain level of symptoms. The probability for death was assumed to be 49% within the critical patients.

The time till hospitalization from the onset of symptoms is assumed to be Gamma distributed with median 1.67 and variance 7.424 [gamma parameters: shape=0.874, loc=0.0, scale=2.915][10] Patients with non severe progression possibly stay at home and the time from onset of symptoms till staying at home is also assumed to be Gamma distributed with median 2.31. and variance 8.365 [gamma parameters: shape=0.497, loc=0.0, scale=3.923].[11] The maximal duration of the infectious period is assumed to be 14 days.[12]

Contact structure and infection transport: Within the households we assume a clique contact structure. Empirical studies have shown that a large fraction of secondary infections are taking place within households.[13] We hence assumed that the probability of a household member to become infected by an already infected household member, who is infectious within a time interval of length T, scales as $1 - \exp(-T/L)$, where $L + 1$ is the household size. Here, the time T is measured in days. Outside of the households we assume that infected individuals create on average $c \cdot T$ secondary infections, given that all contacts of these individuals are susceptible, where c is an intrinsic parameter. Note the time T being infectious is different for contacts inside and outside the household. The out-reproduction number R^* is defined as the expectation of $c \cdot T$, which is equal to $2.34c$ under our assumptions of disease progression within patients. The actual number of secondary infections of an individual outside the household is assumed to be Poisson distributed with mean $(c \cdot T)$. The total reproduction number R_0 is given by the sum of R^* and the number of secondary infections generated inside the household. The duration of the infectivity time T implicitly depends on age. This is due to the fact that infectivity time is reduced for individuals with severe disease progression, as those patients become hospitalized. Severe progression is in turn more probable for older infected individuals. The outside household contact structure was intentionally chosen to be simple in order to have only one relevant and easily interpretable parameter in the model. We do not consider super-spreading events that could enhance the progression of the epidemic. Such events might have a strong impact at the beginning of an epidemic outbreak but, as the number of cases increases, the mean number of secondary infections R will dominate the evolution.

Testing and quarantine: We included additional model features to study the effect of testing followed by household quarantine in case the testing was positive. We assume that individuals with severe symptoms will always be detected and individuals with mild symptoms will be detected with probability q two days after the onset of symptoms. A detection is followed up by quarantine of the corresponding household with the effect that all out-household contacts by members of those households are stopped. The parameter q can be interpreted as the likelihood that a person with characteristic mild symptoms will be tested for COVID-19.

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