Model-based approach for determining COVID-19 incidence for different testing intensities

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ECMTB 2022, Heidelberg
22nd of September, 2022

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Introduction to the problem

- Different approaches to COVID-19 mitigation througout the world

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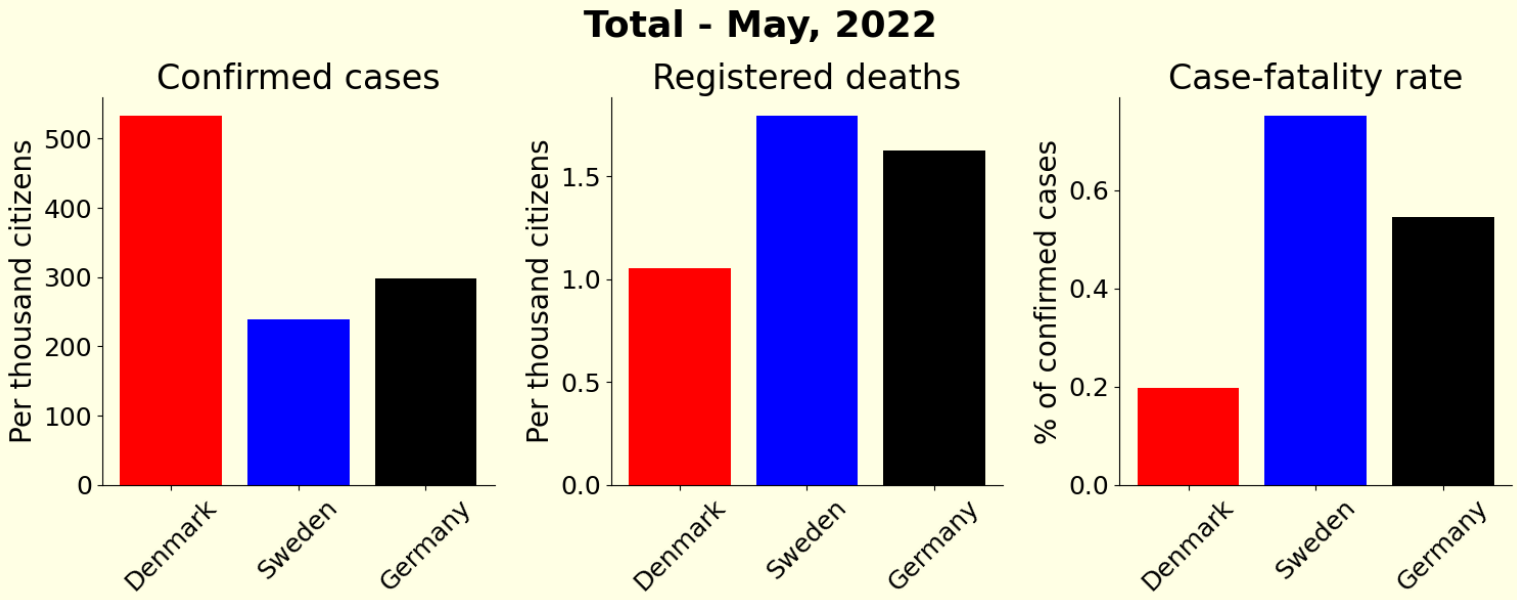
Let's look at some data...



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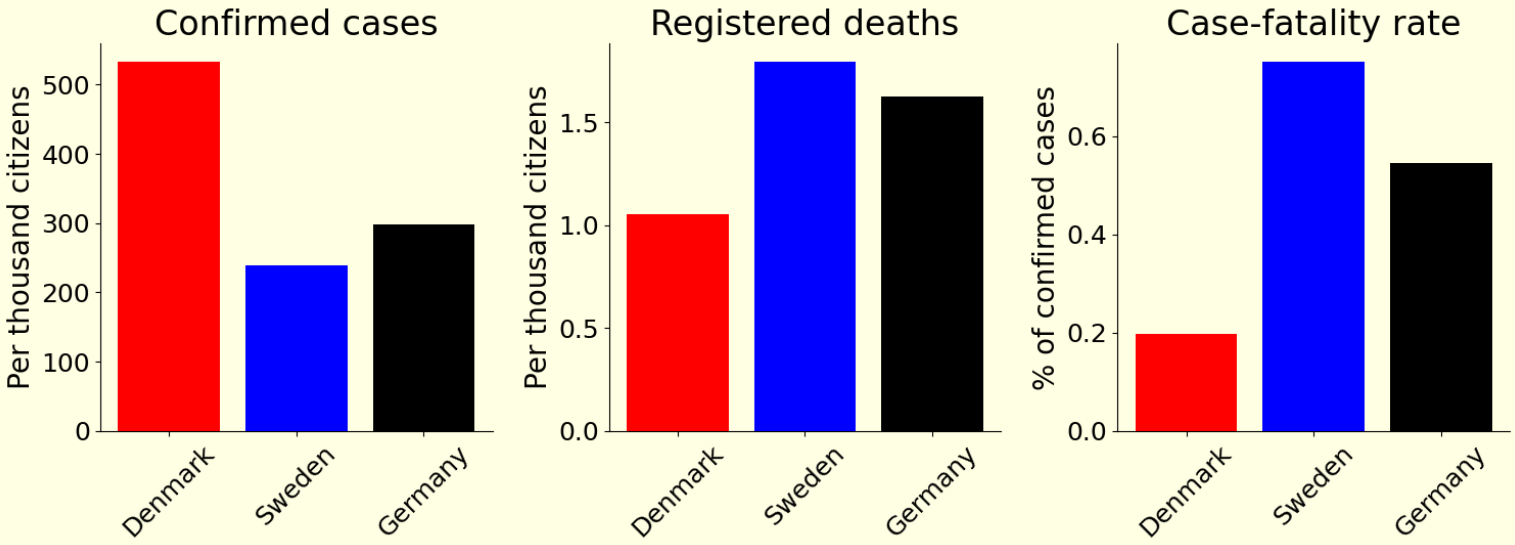
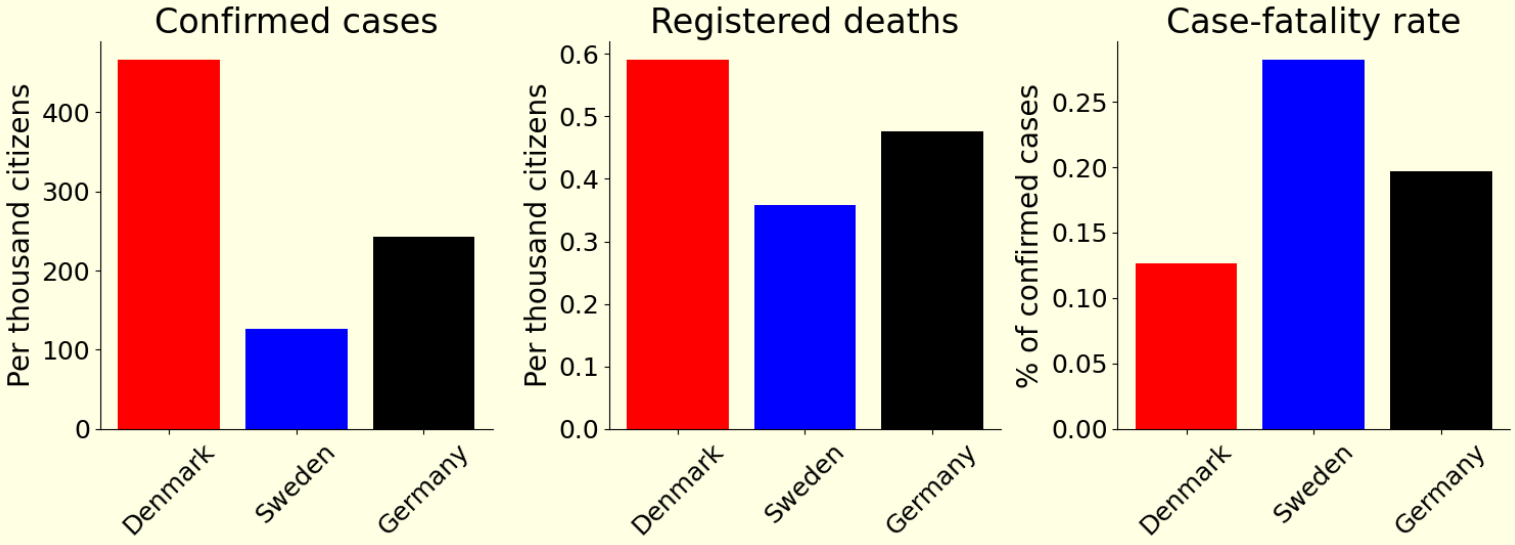
Total - May, 2022



From November 1st, 2021 to May 1st, 2022



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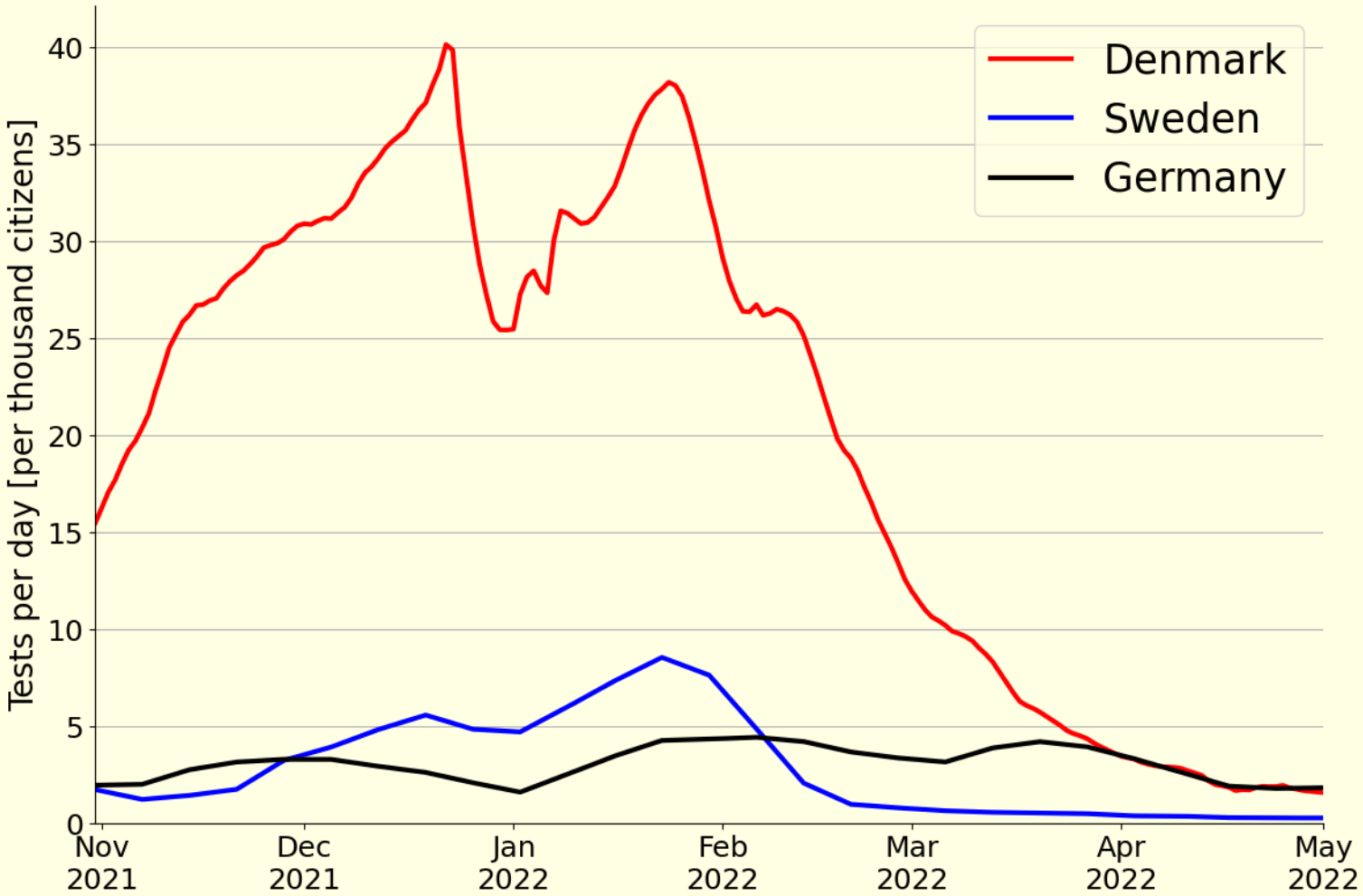

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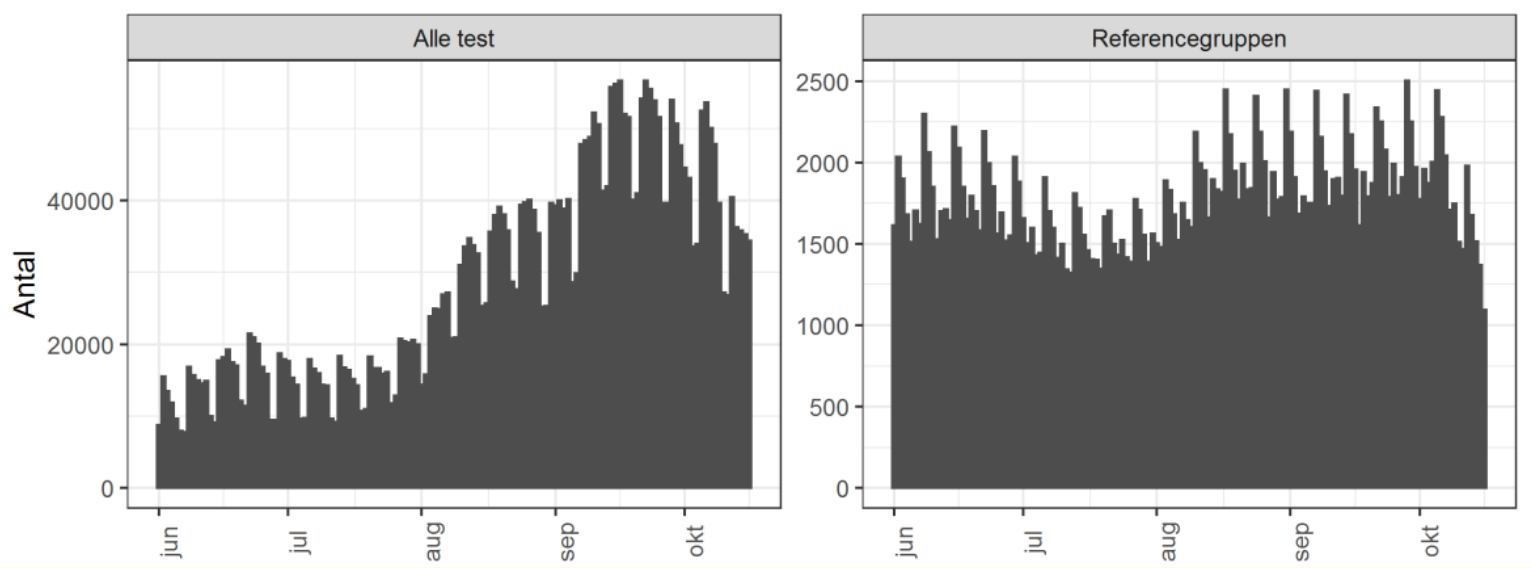
Approach of Danish Health Agencies

Testing activity for non-COVID related hospitalizations in Denmark remained stable throughout 2020, despite large variation in testing activity in the population.



Approach of Danish Health Agencies

A method for correcting observed incidence was developed by Danish health agencies:

$$I_{corrected} = I_{observed} \left(\frac{T}{50,000} \right)^{0.7}$$

where T is the number of tests on the given day, $I_{observed}$ the number of positive tests, and $I_{corrected}$ a measure for the expected number of positive tests if the number of tests the given day was $50,000$.
The 0.7 factor was estimated from data, and later updated to 0.3.

(SSI, 2020; *Ekspertrapport af d. 23. oktober 2020 - Incidens og fremskrivning af COVID-19 tilfælde*)

Our approach

- We aim to determine the ratio between total cases of COVID-19 and observed cases.

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- By extending the classic SIR-model to include voluntary testing, we can identify the proportion of cases observed.
- Investigating the relationship between testing intensity and the ratio of observed cases, a correction-factor can be determined.

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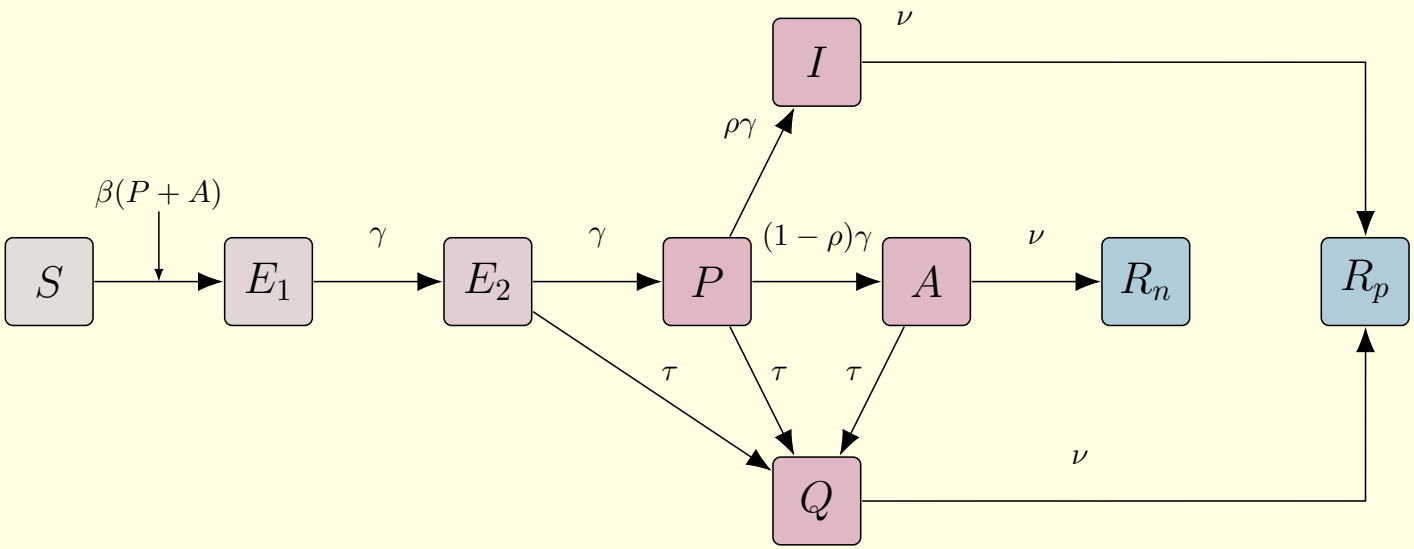
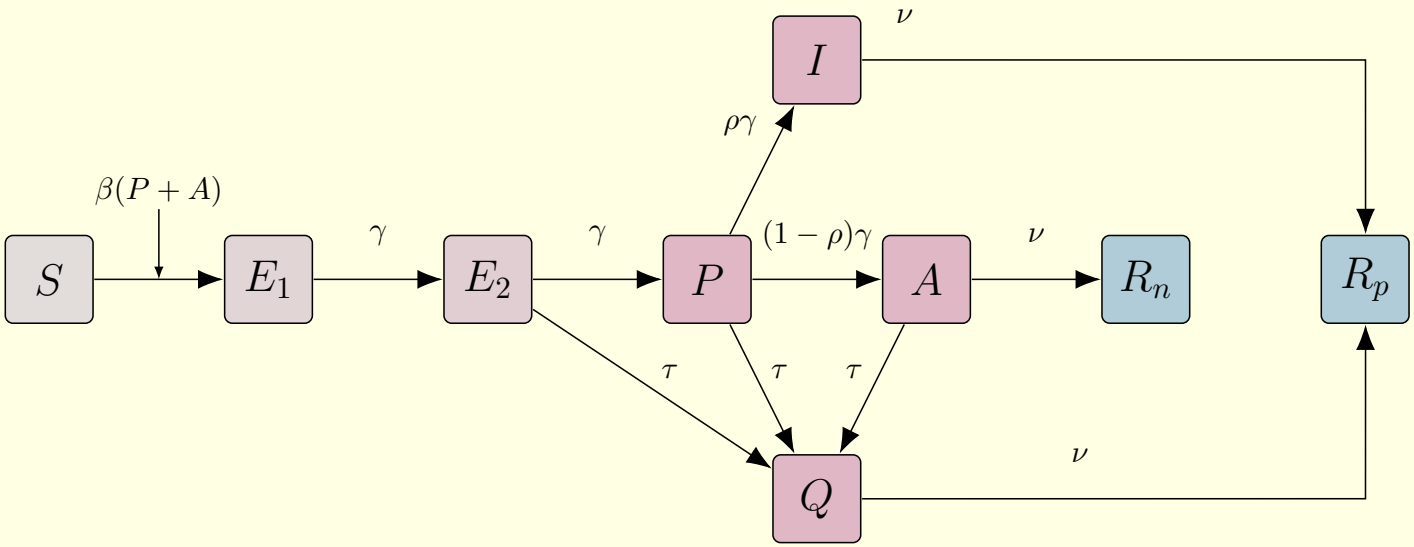
The model


I
ν
$\rho\gamma$
$\beta(P+A)$
S
E_1
γ
E_2
γ
P
$(1-\rho)\gamma$
A
ν
R_n
R_p
τ
τ
τ
ν
Q

The model



$$\dot{S} = -\beta S(P+A)$$
$$\dot{E}_1 = \beta S(P+A) - \gamma E_1$$
$$\dot{E}_2 = \gamma E_1 - \gamma E_2 - \tau E_2$$
$$\dot{P} = \gamma E_2 - \gamma P - \tau P$$
$$\dot{I} = \gamma\rho P - \nu I$$
$$\dot{A} = \gamma(1-\rho)P - \nu A - \tau A$$
$$\dot{Q} = \tau(E_2 + P + A) - \nu Q$$
$$\dot{R}_p = \nu Q + \nu I$$
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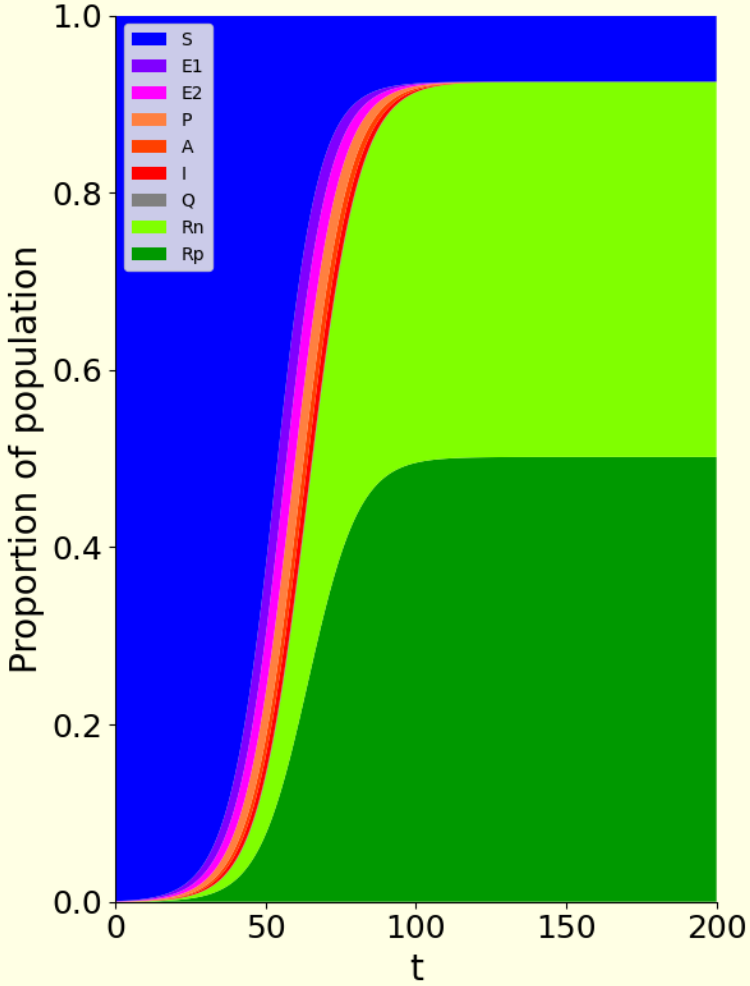
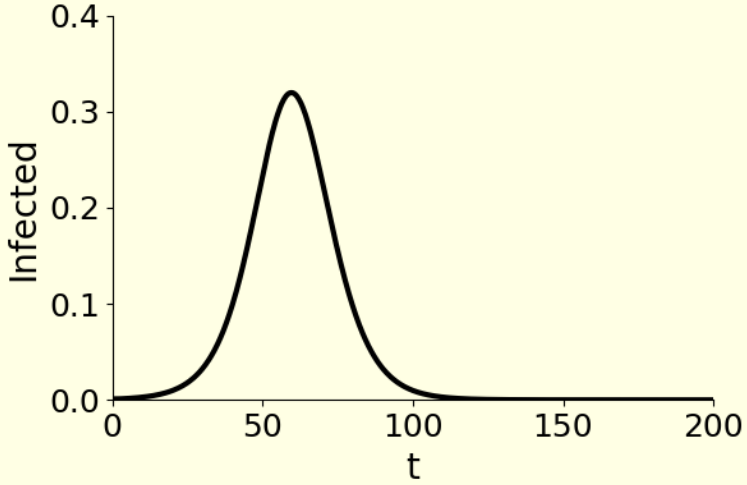
Symbol	*Description*	*Default value*
β	Infectivity	2/3
ν	Rate of recovery	1/3
γ	Rate of disease progression	1/3
ρ	Fraction of symptomatic cases	1/2
τ	Rate of testing	0 to 0.5

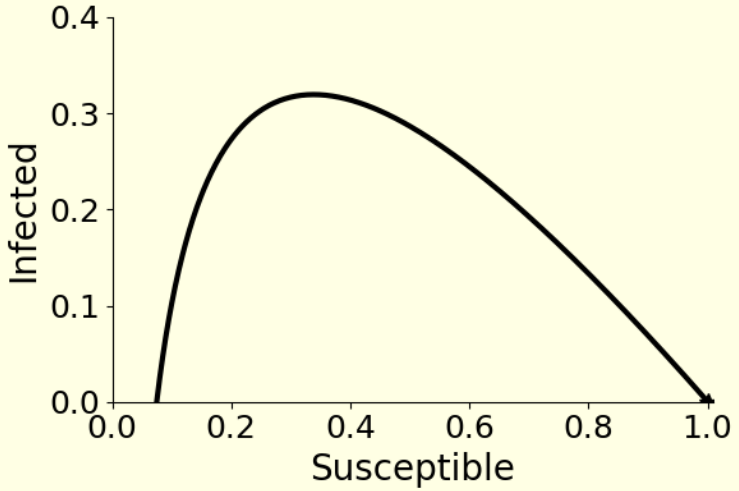
All rates units of day^{-1}. Approximate R_0 of 1.4 initially.

General model dynamics

General dynamics like classic SIR-model.







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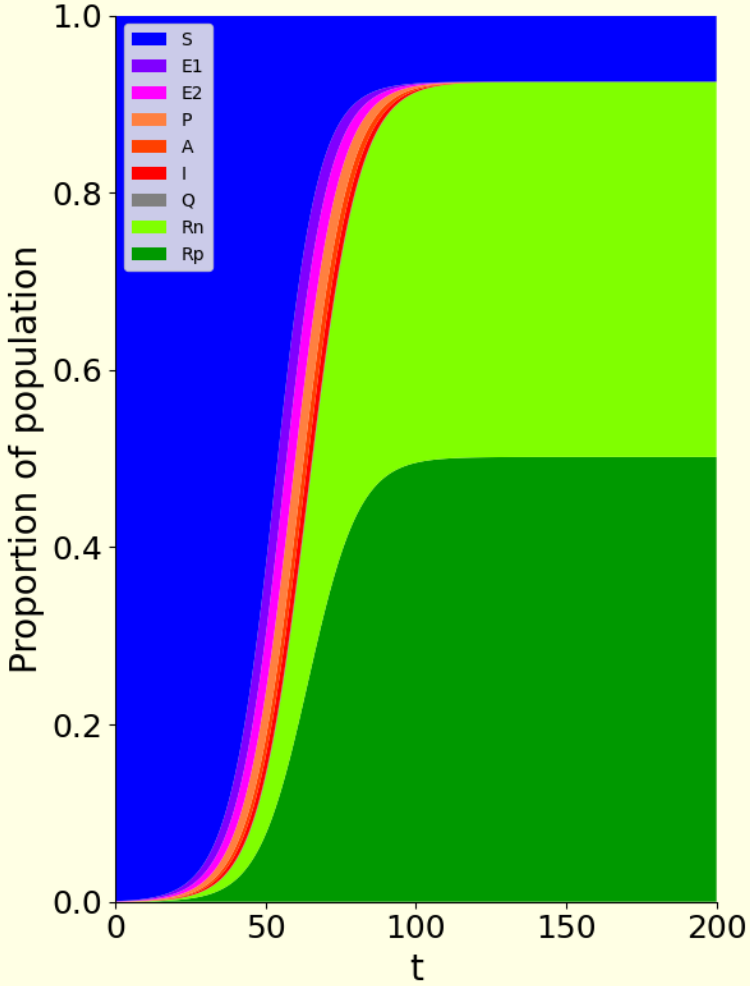

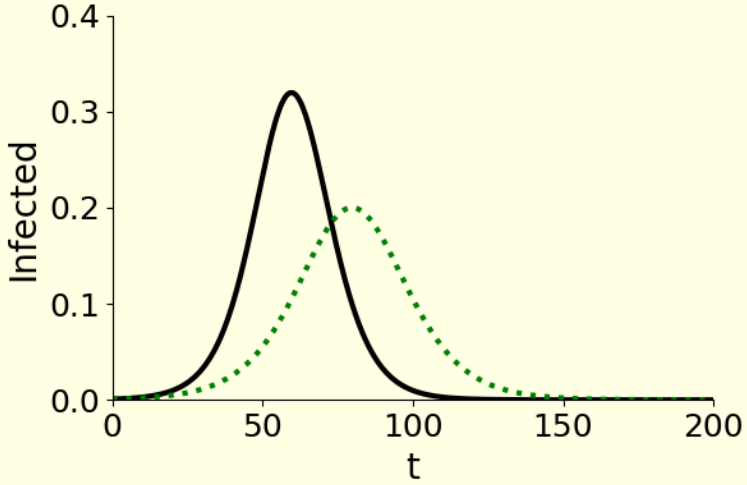

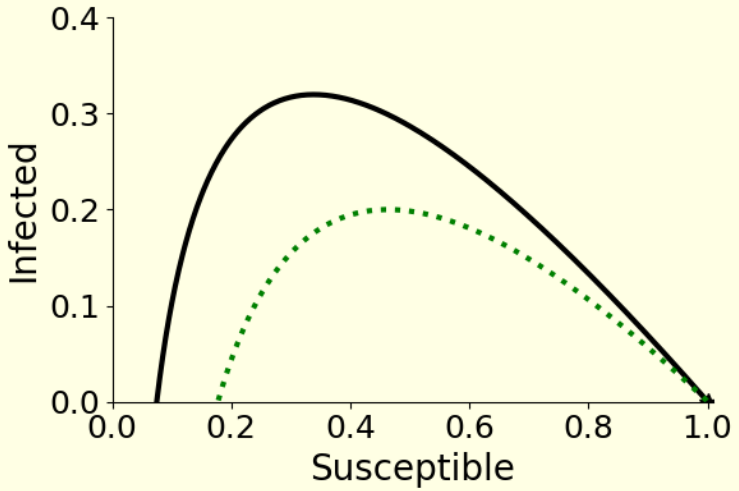

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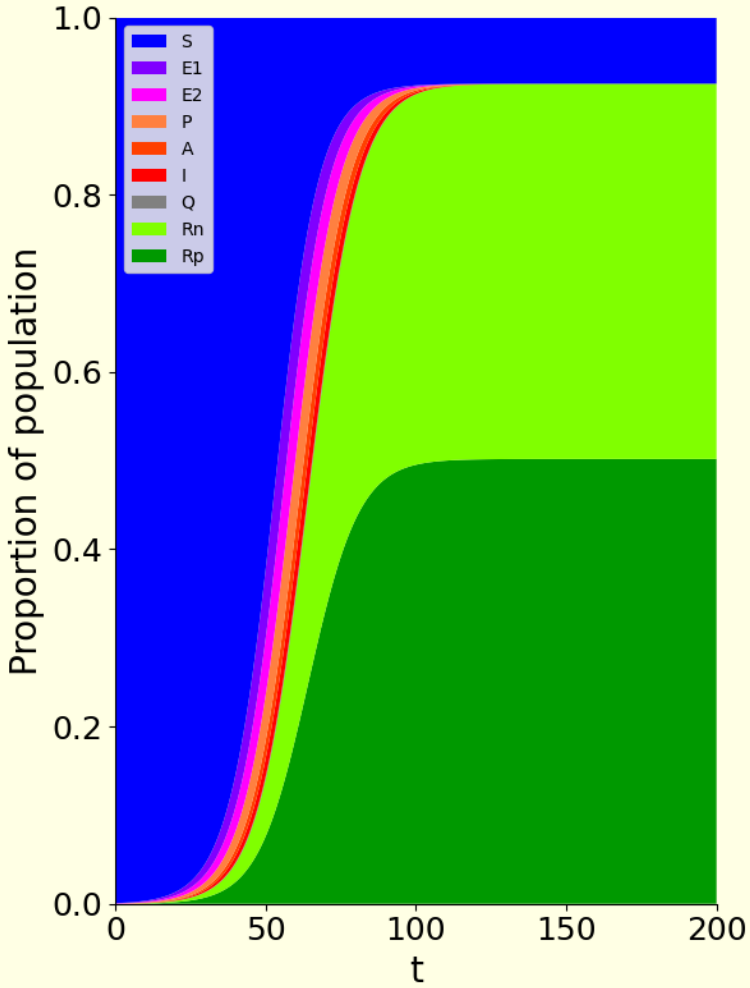

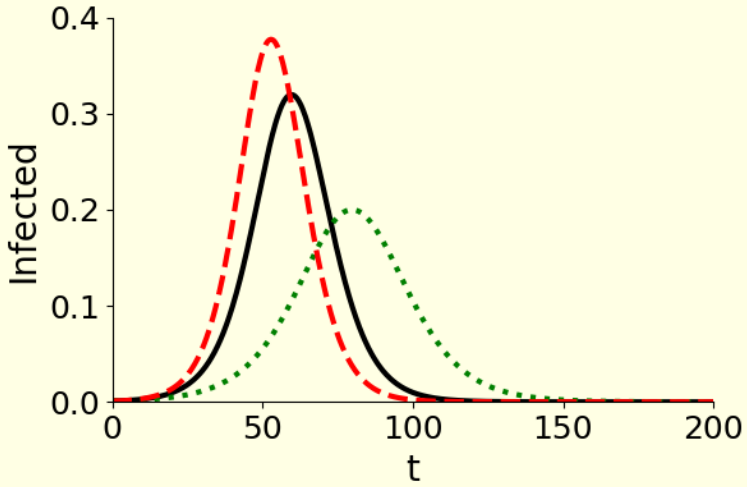

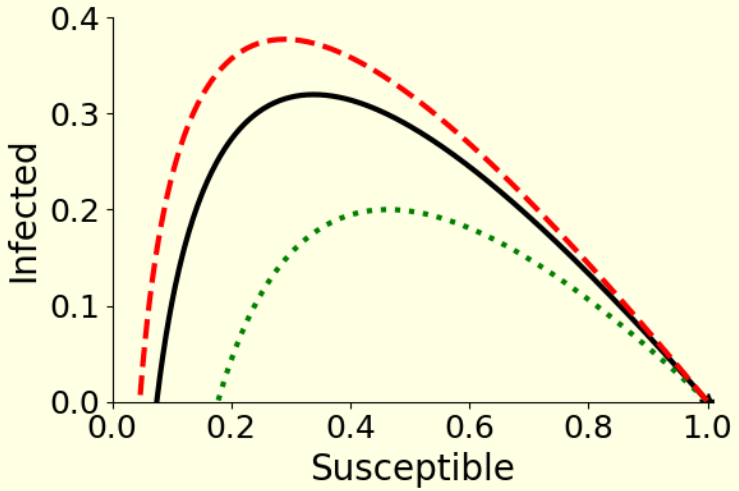

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Analysis of epidemic final size

We consider the fraction of cases identified:

$$K = \frac{r_p}{r_p + r_n} \tag{1}$$

where $r_p = \lim_{t\to\infty} R_p(t)$ and $r_n = \lim_{t\to\infty} R_n(t)$.

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$$K = 1 - \left(\frac{\nu}{\nu+\tau}\right)\left(1 - \frac{\tau}{\gamma+\tau}\right)\left(1 - \frac{\gamma\rho+\tau}{\gamma+\tau}\right) \tag{2}$$

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(Andreasen, V. (2018). *Epidemics in Competition: Partial Cross-Immunity. Bulletin of Mathematical Biology*, 80(11), 2957-2977. https://doi.org/10.1007/s11538-018-0495-2)

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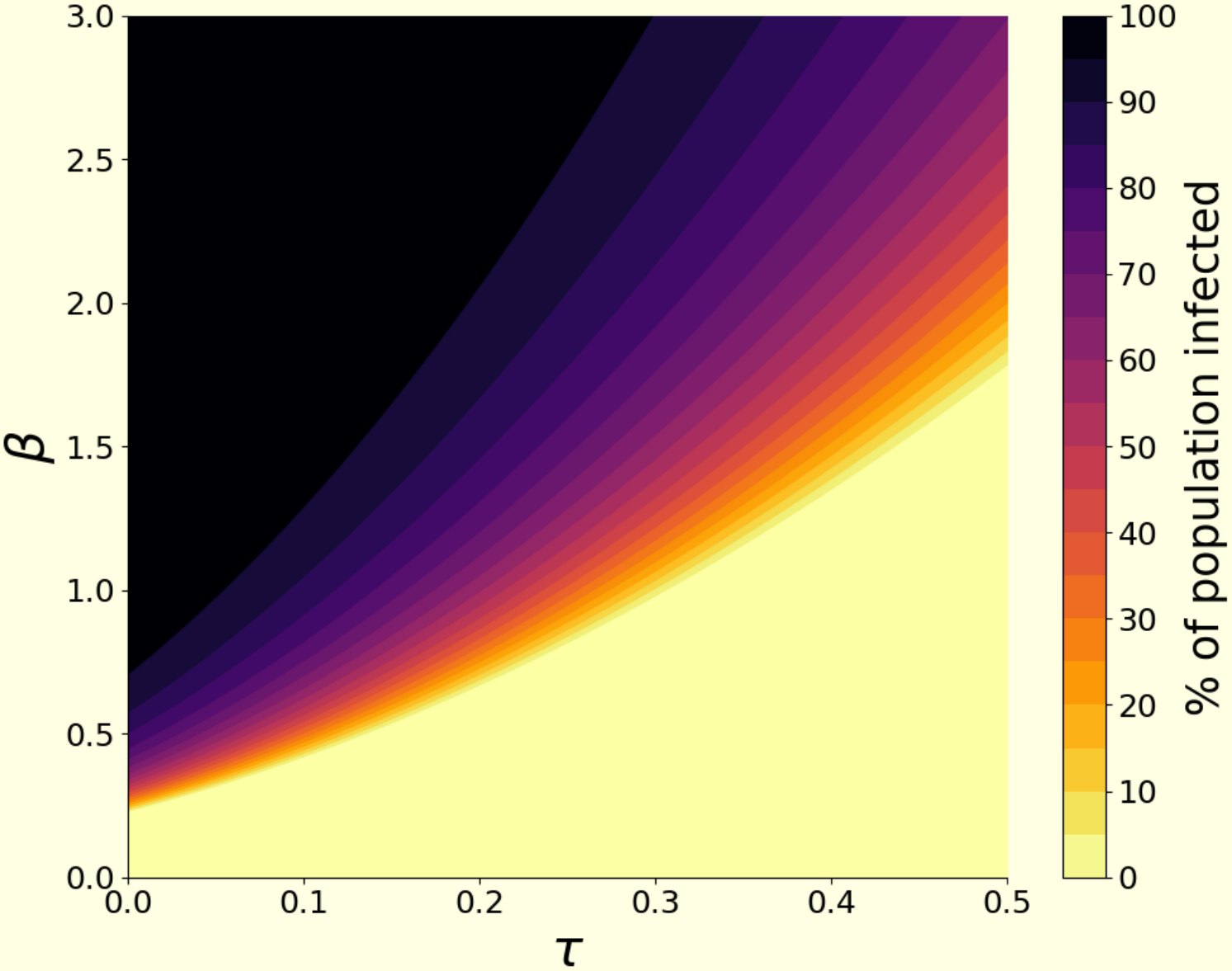
Determining (τ, β) for fixed final size



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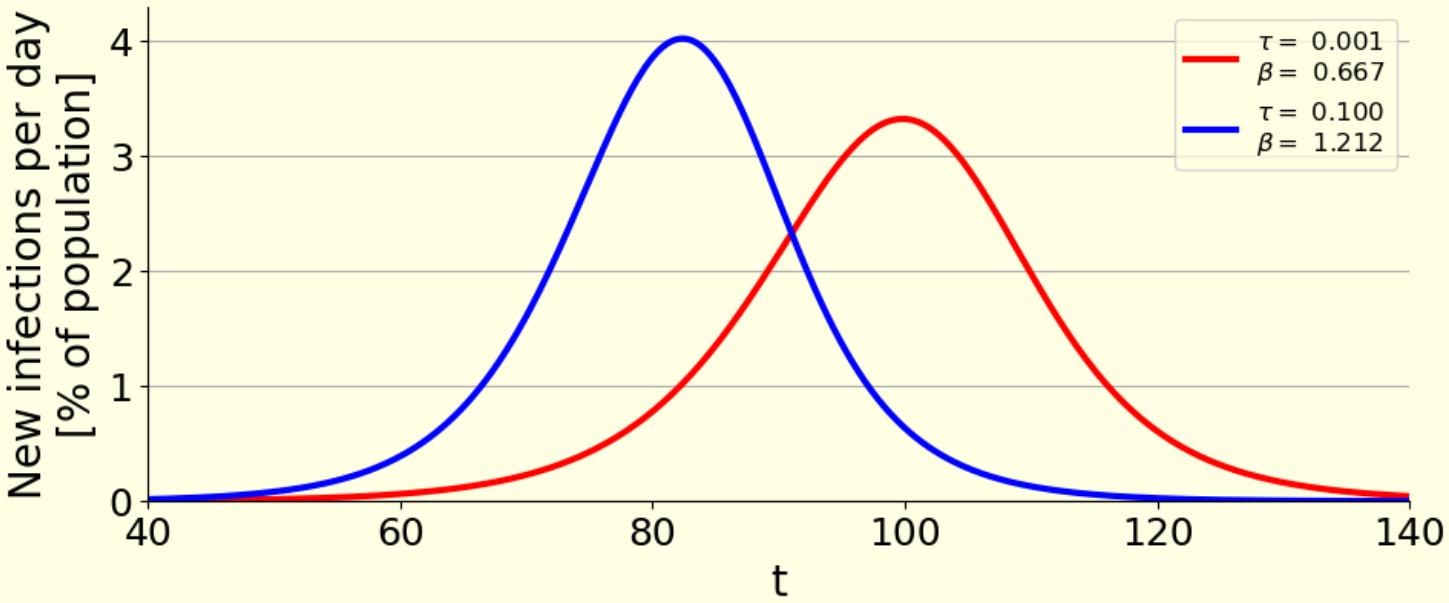

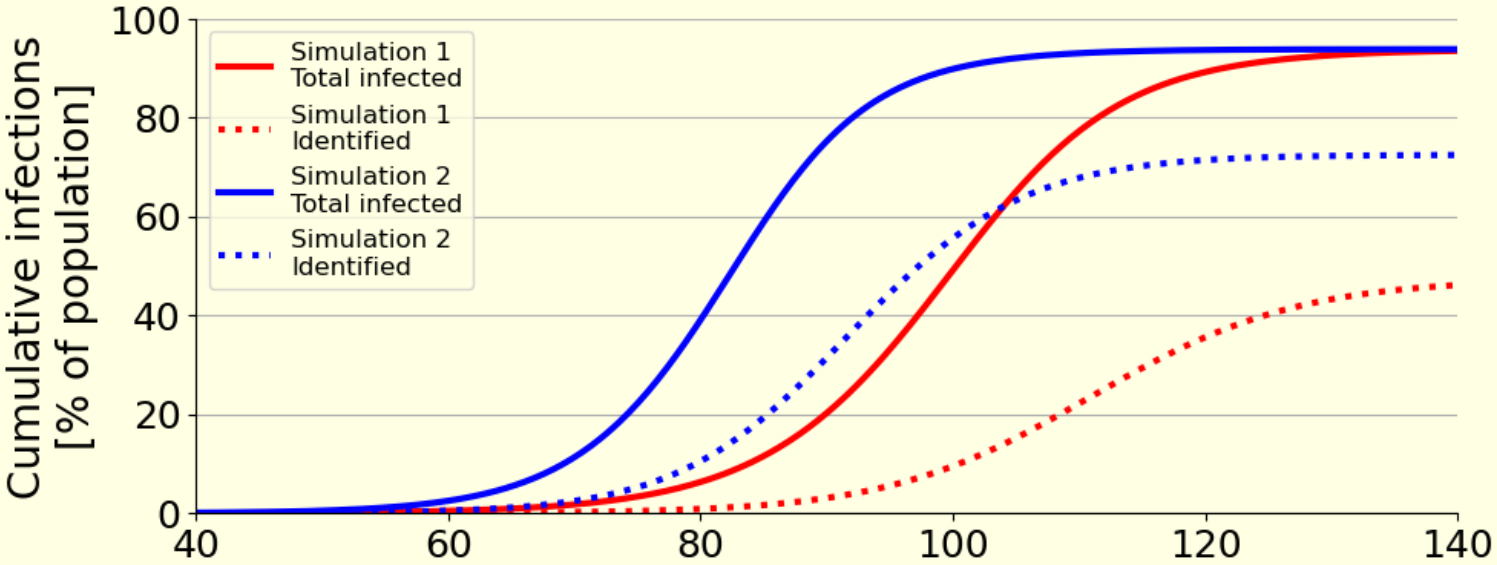

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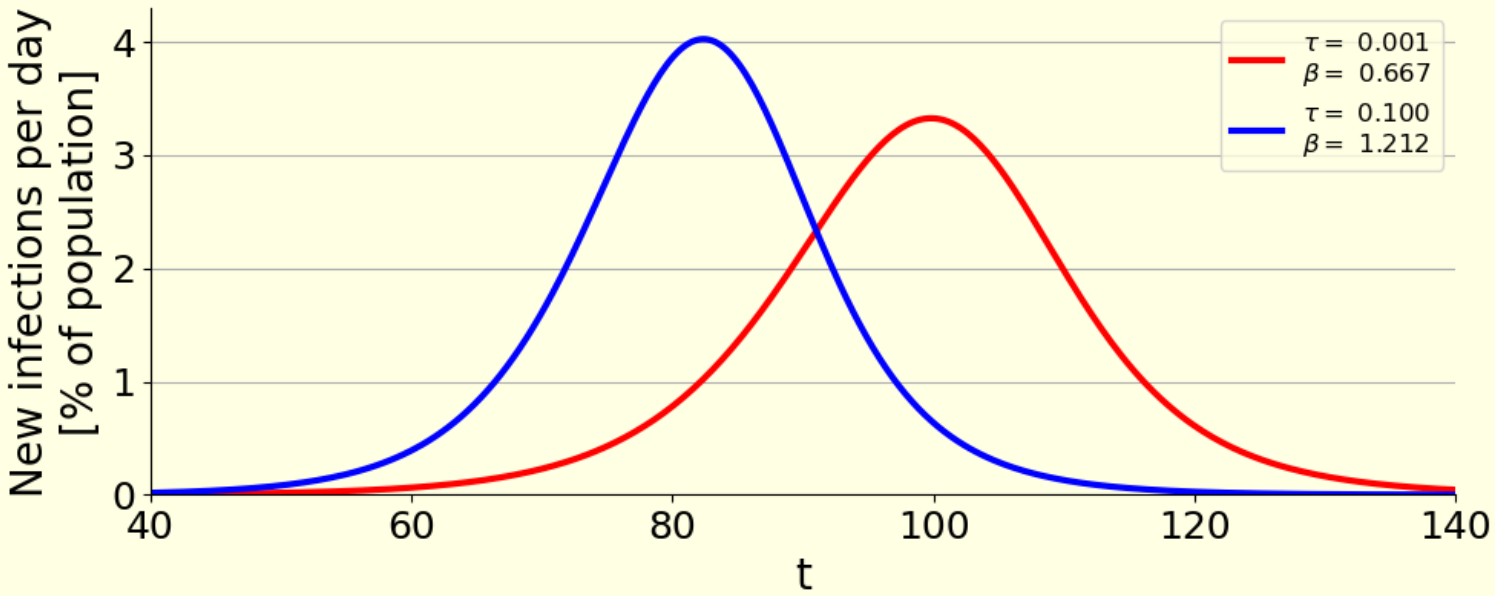

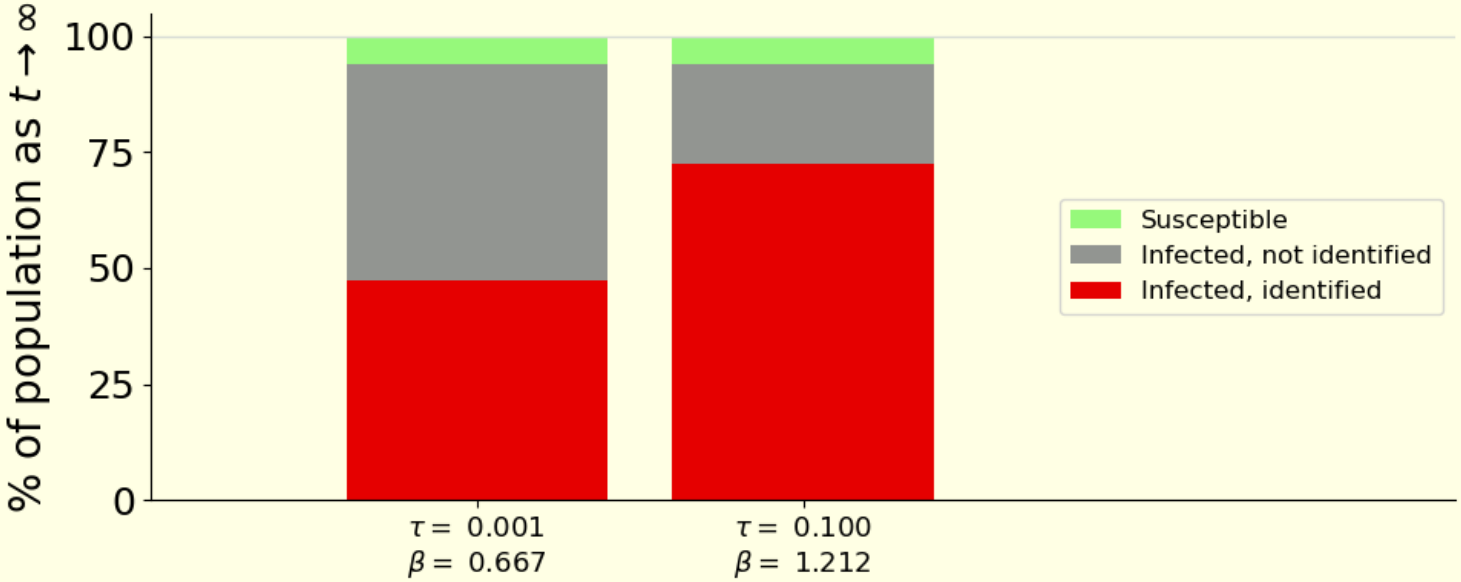

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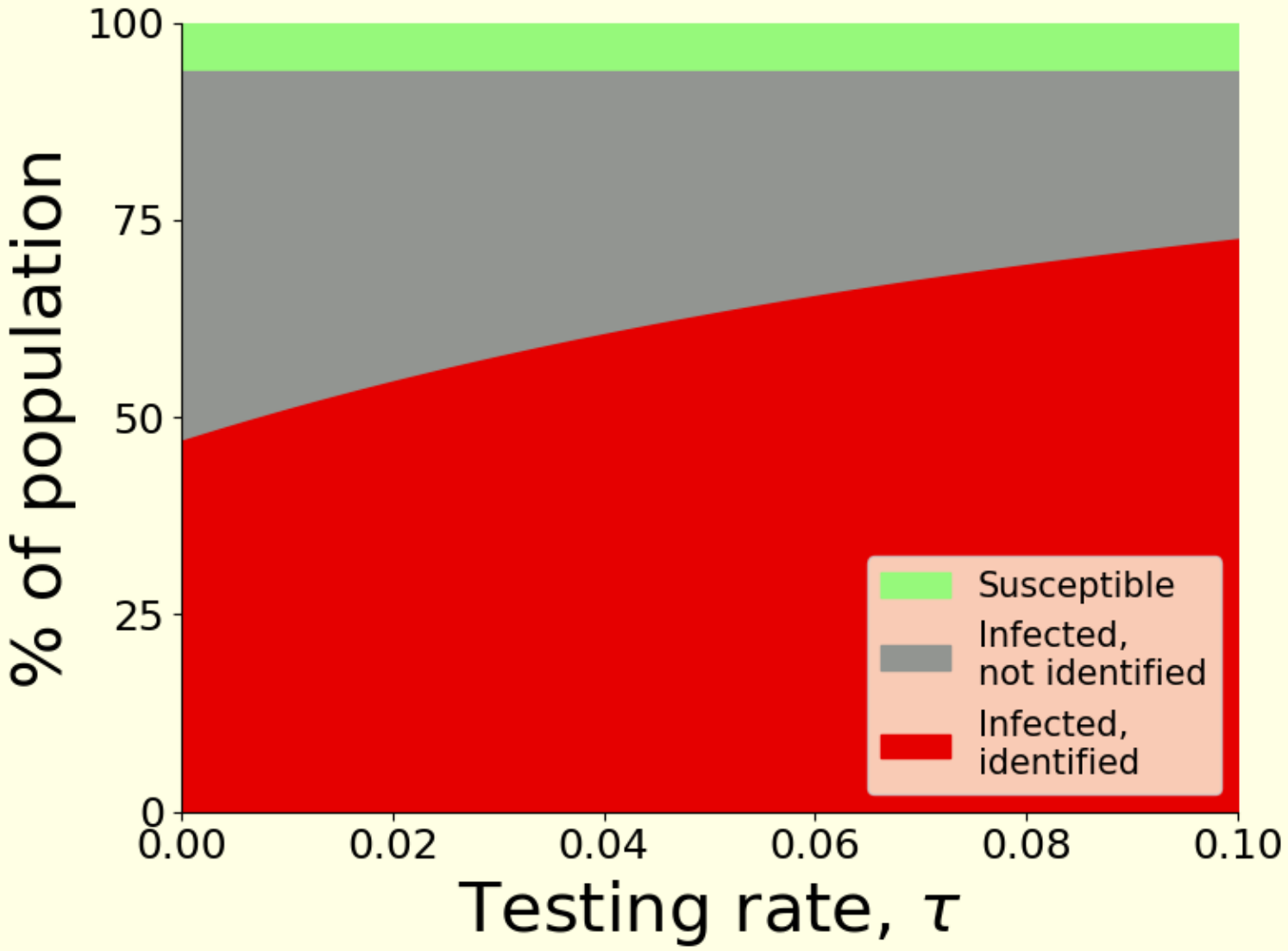

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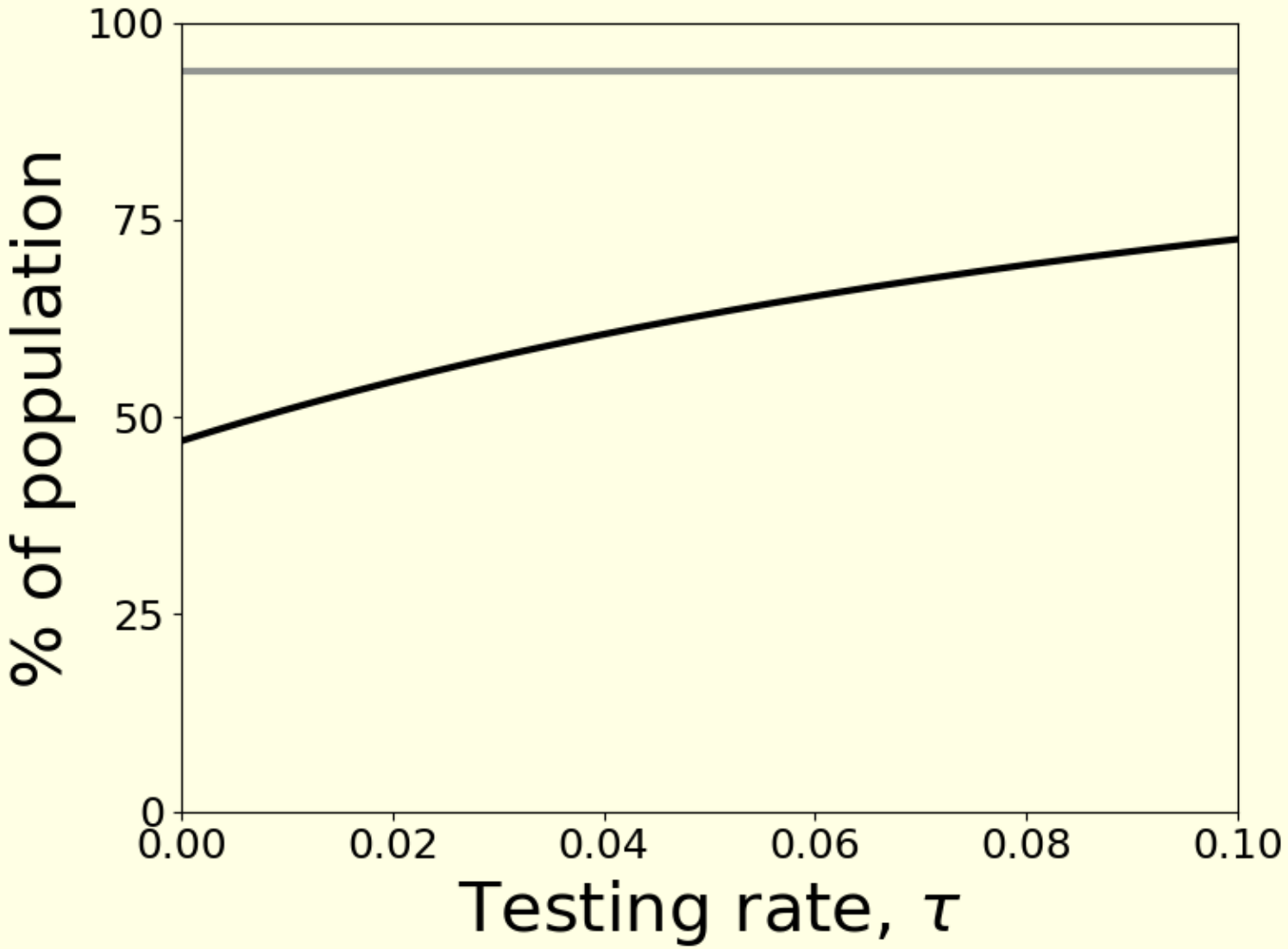

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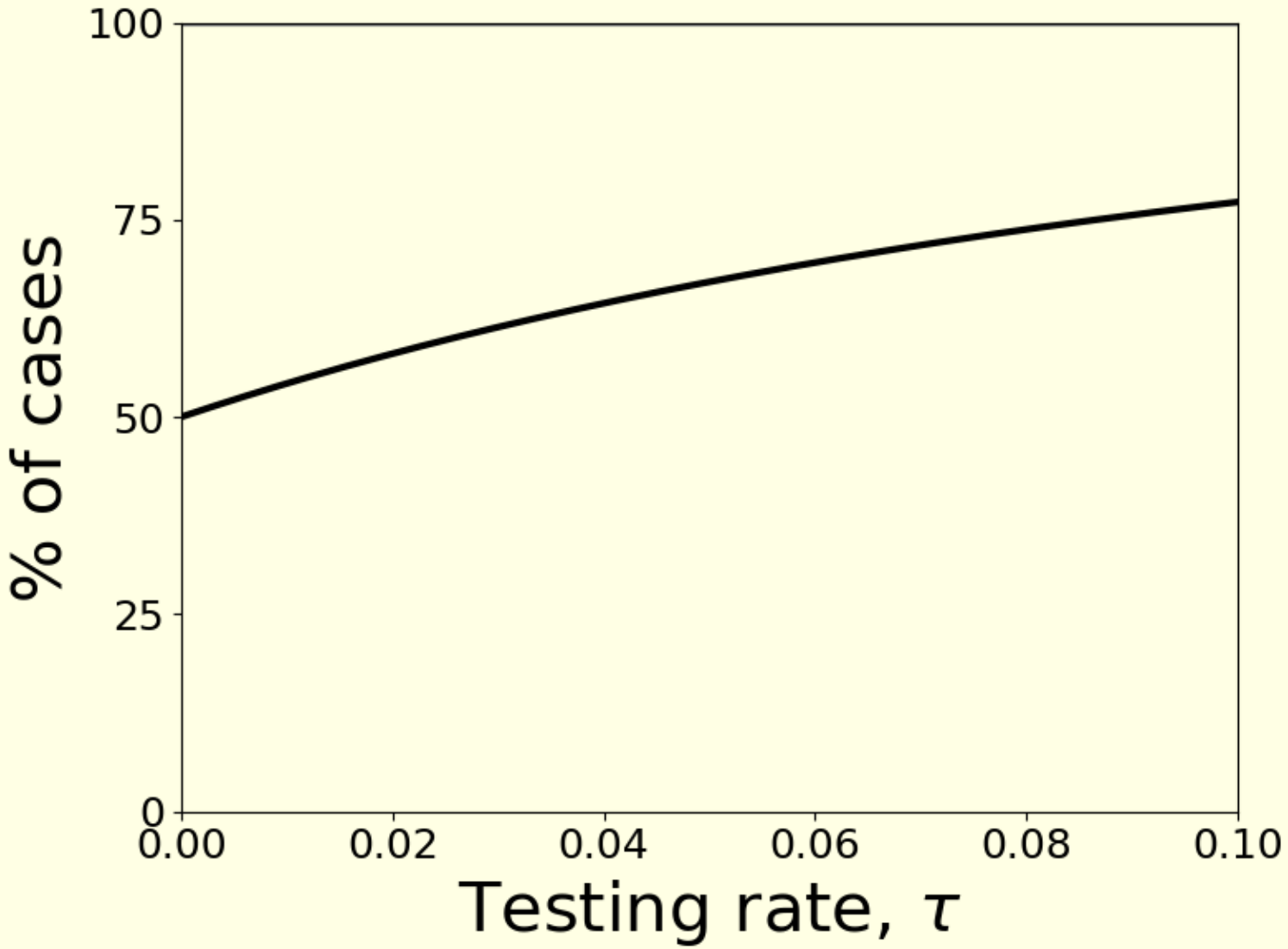

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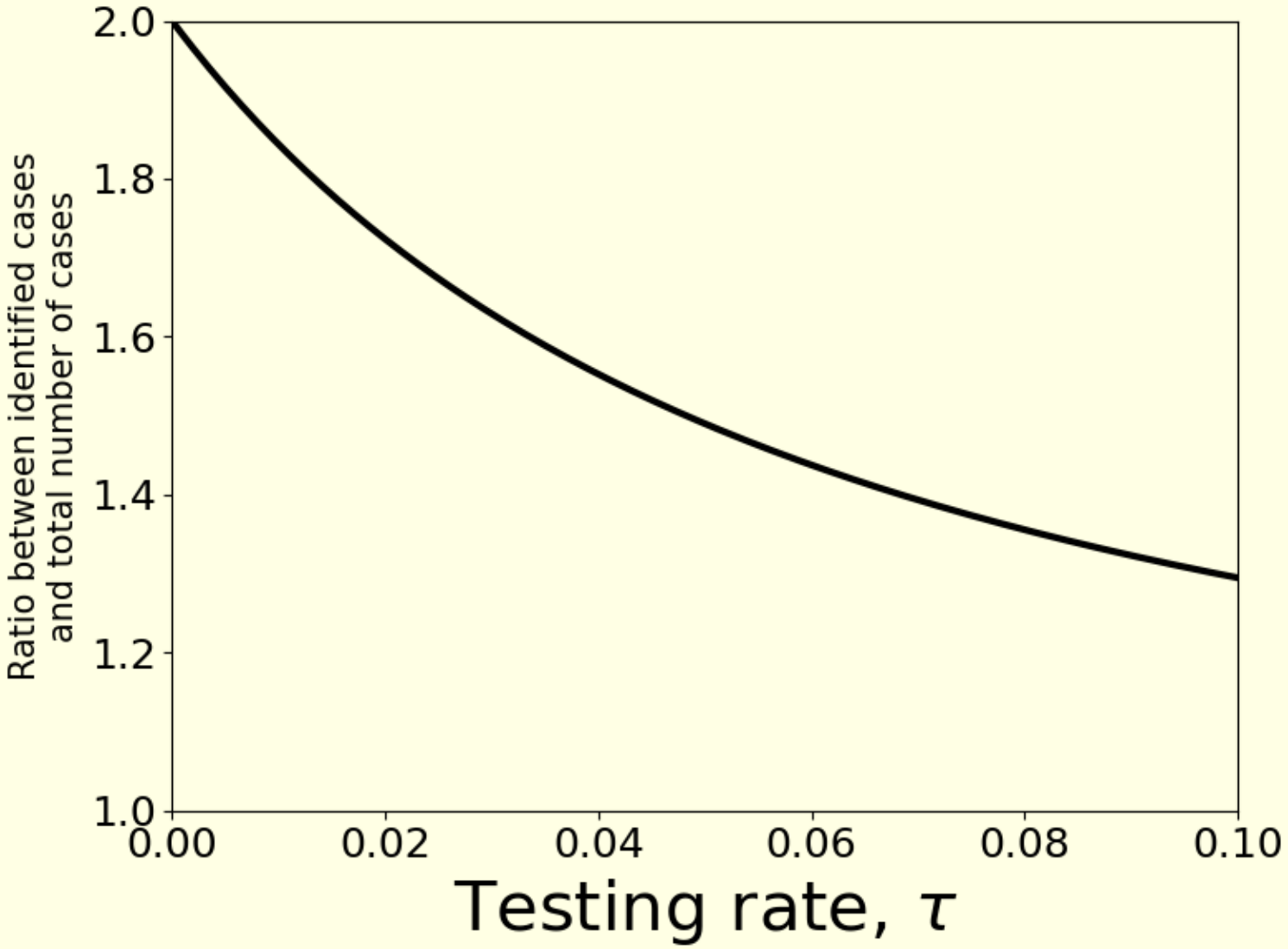

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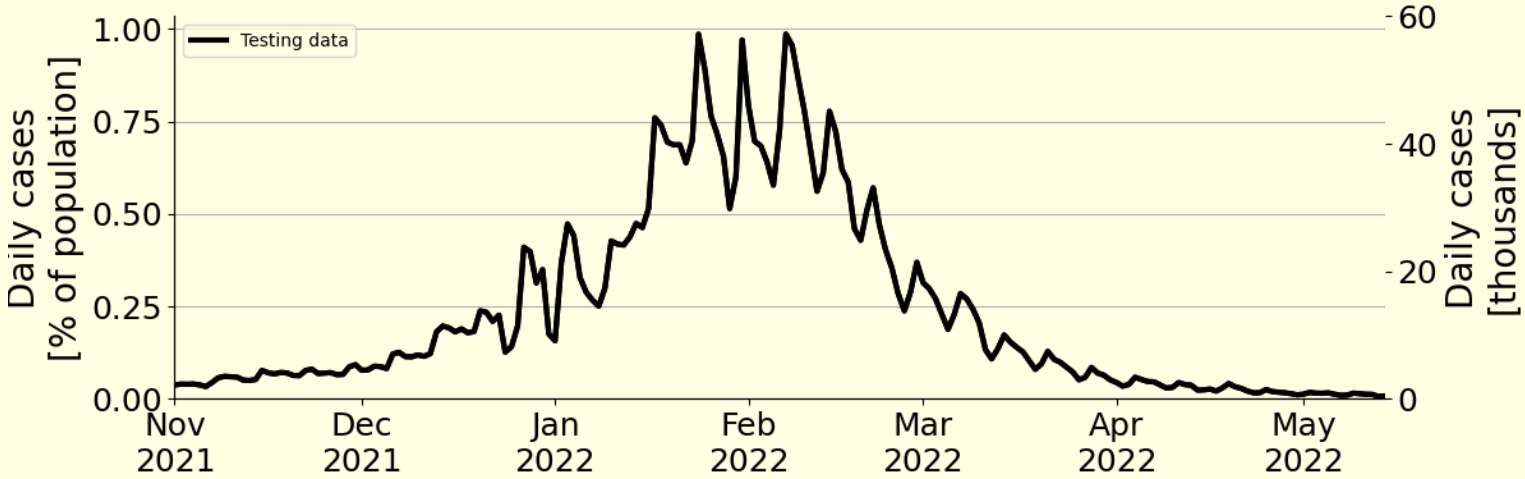
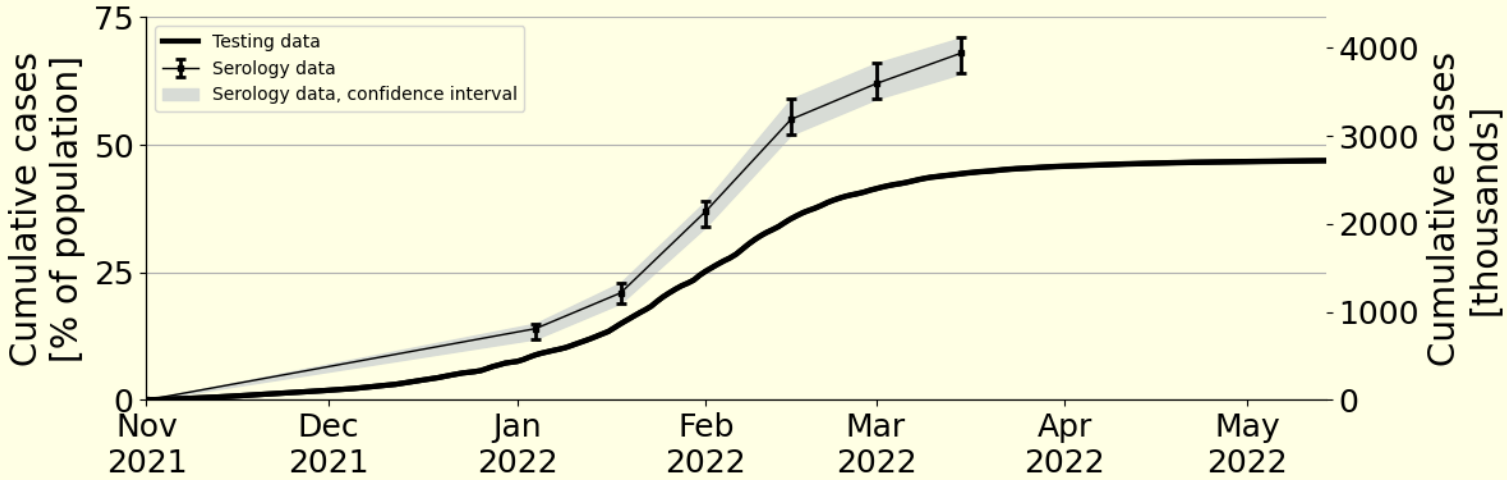
The Danish data

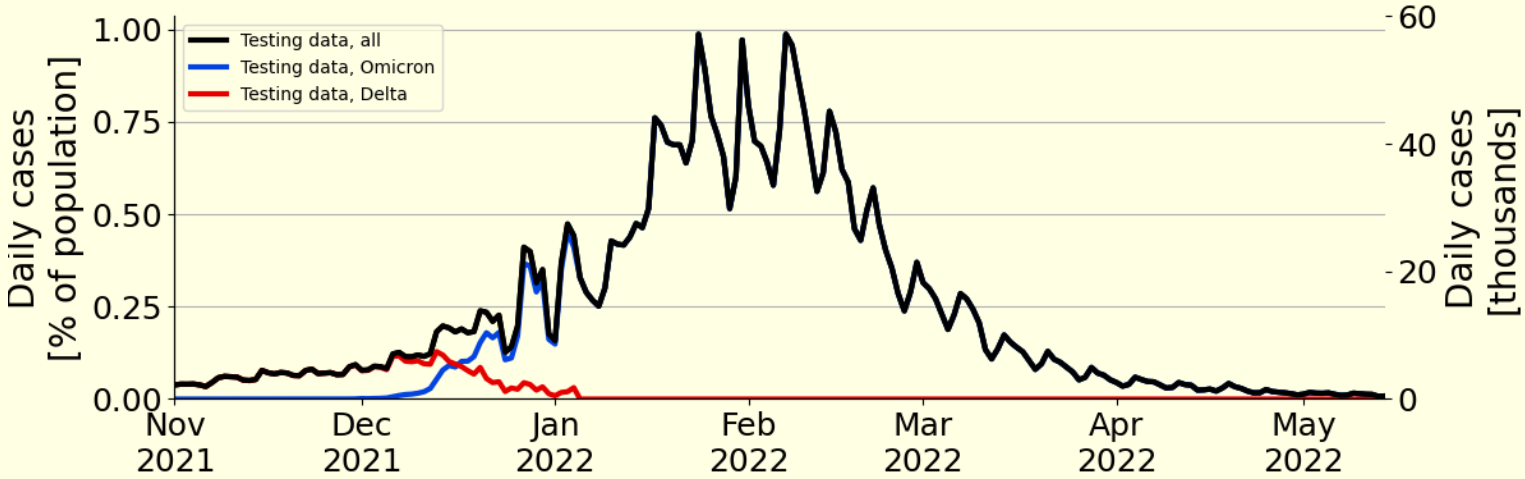
Daily cases and serology from blood-donors

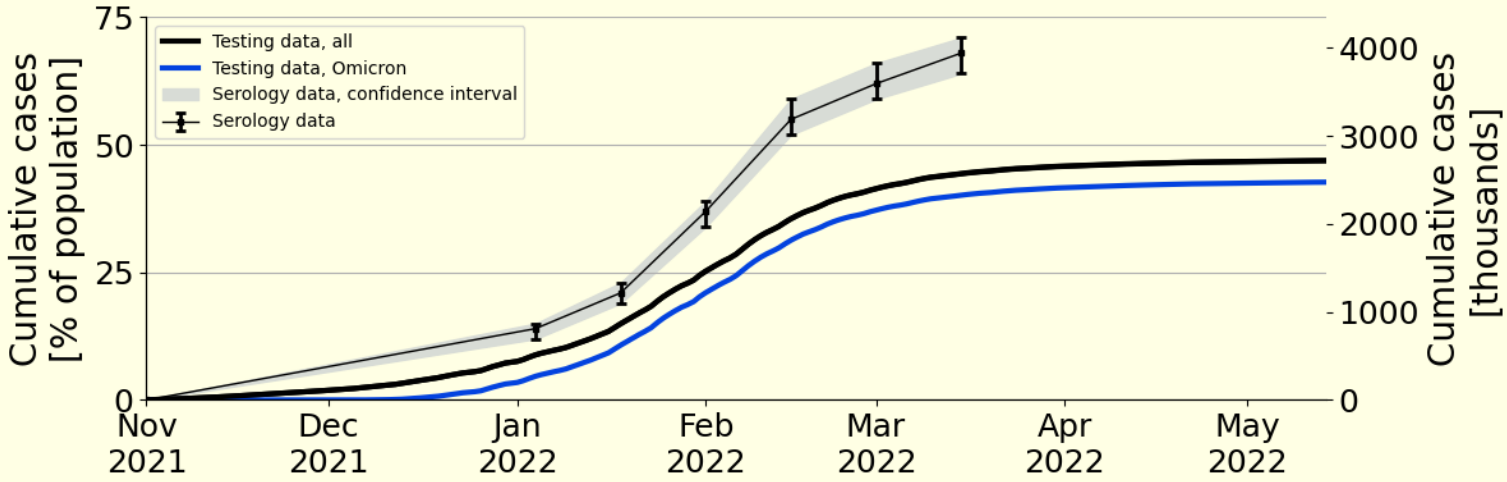




The Danish data

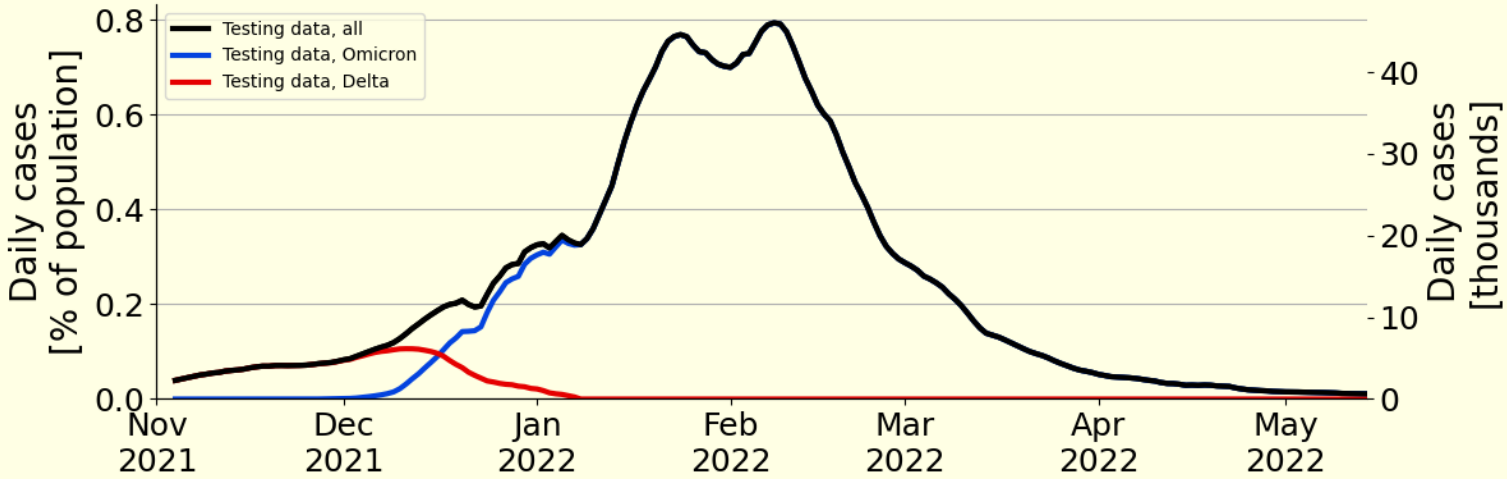
December 2021: Variant-sampling of 80 to 90% of cases.

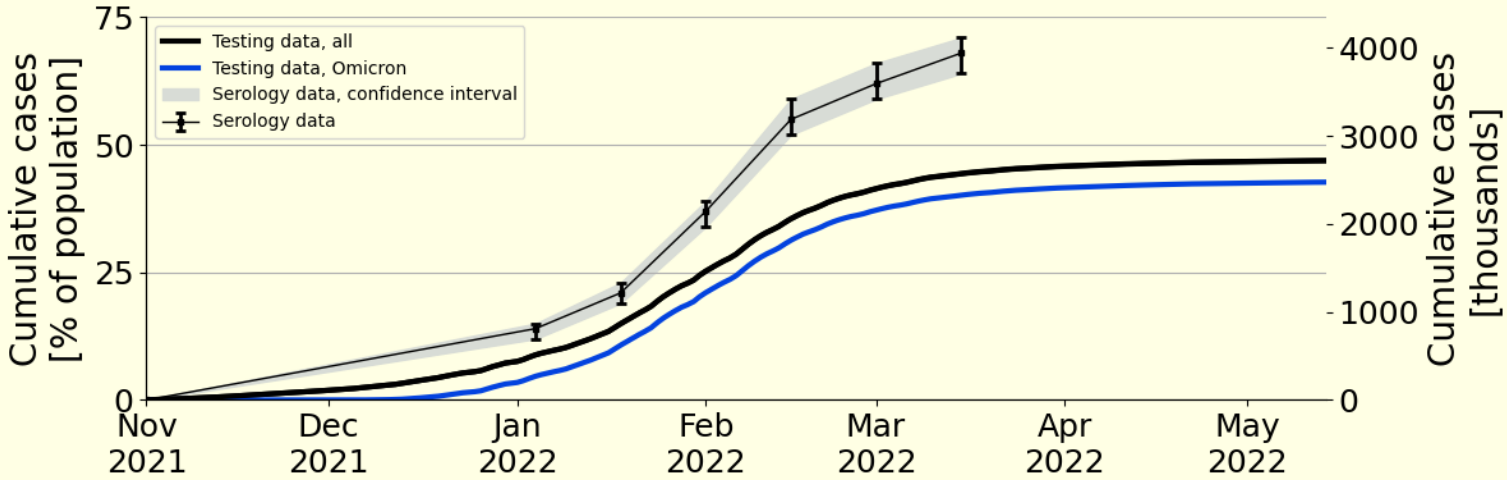




The Danish data

Smoothing: 7-day running mean.





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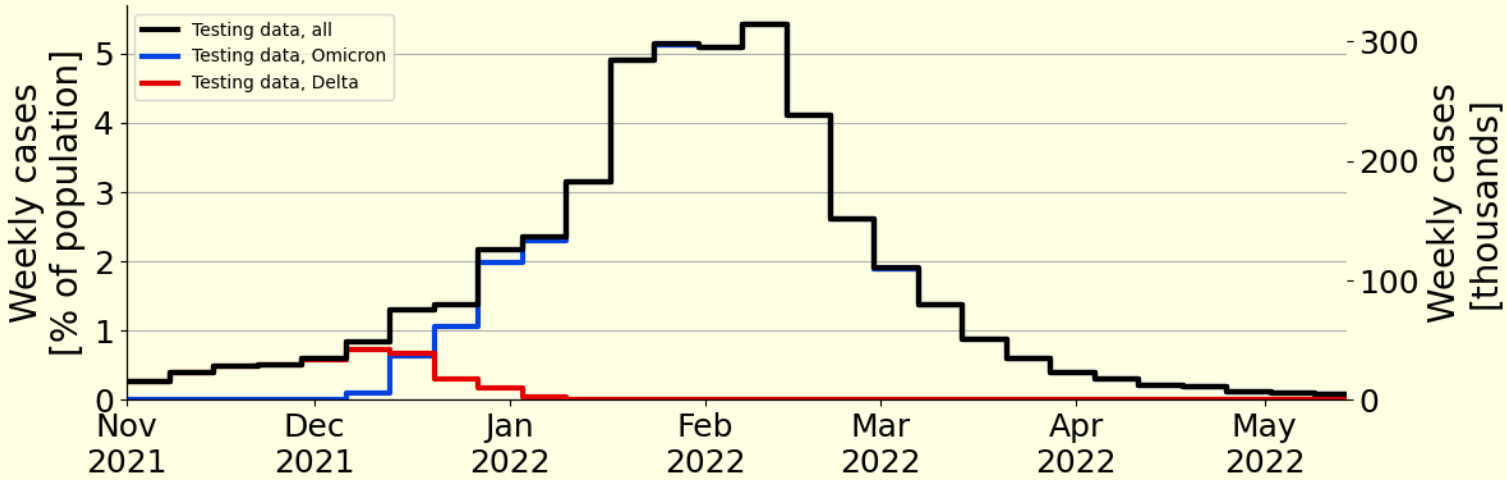
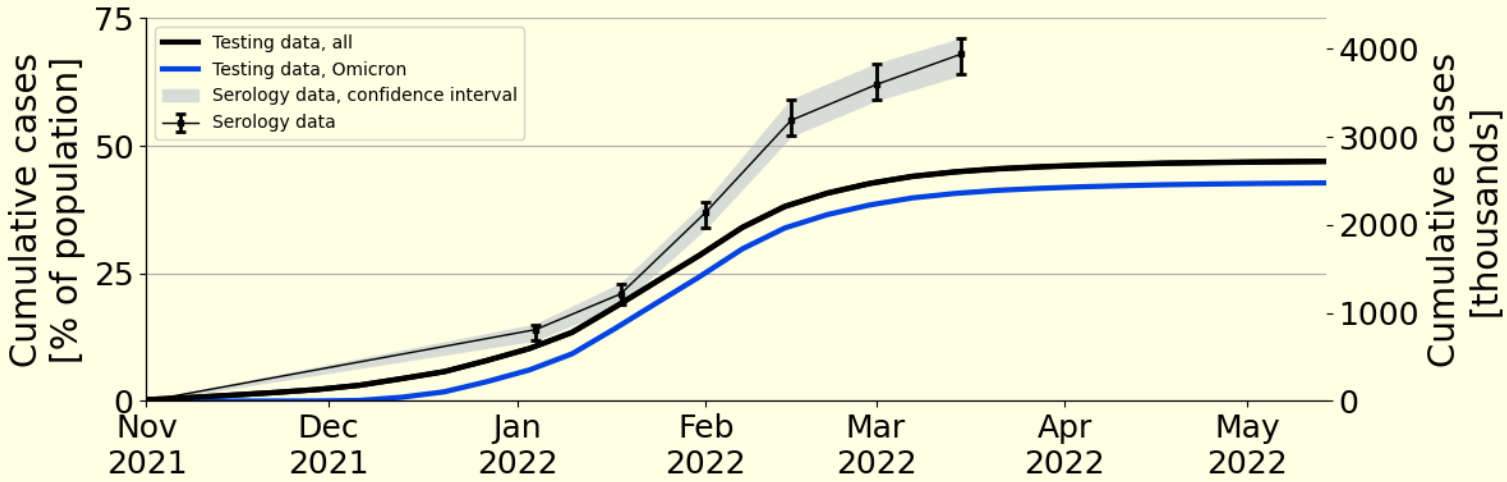
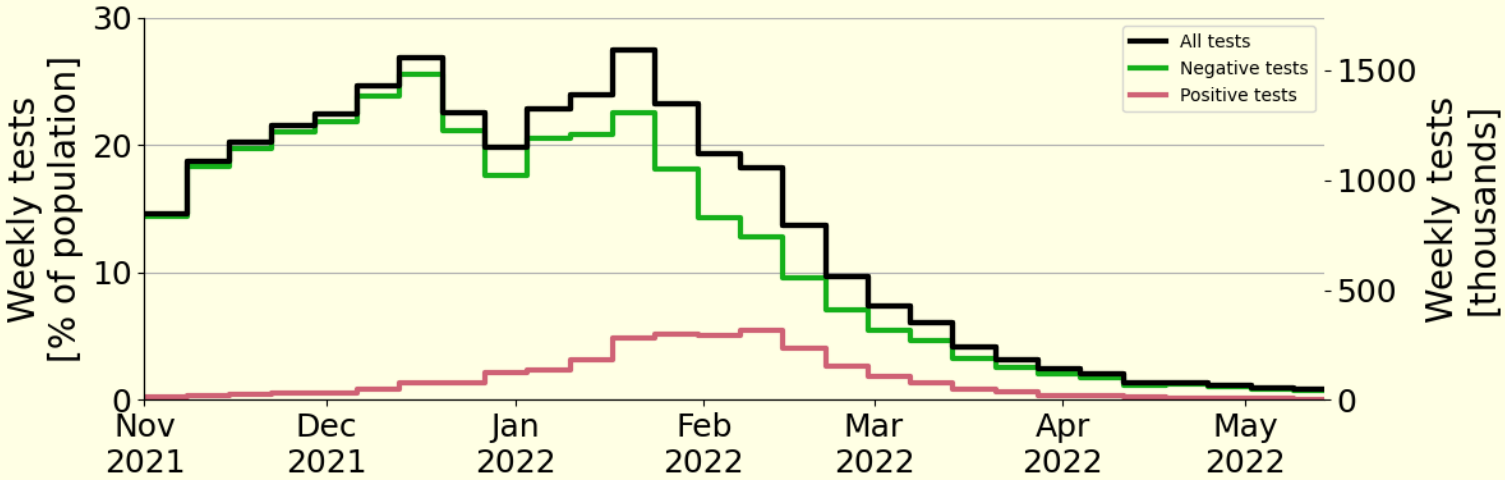
Weekly sums (Monday to Sunday)





The Danish data

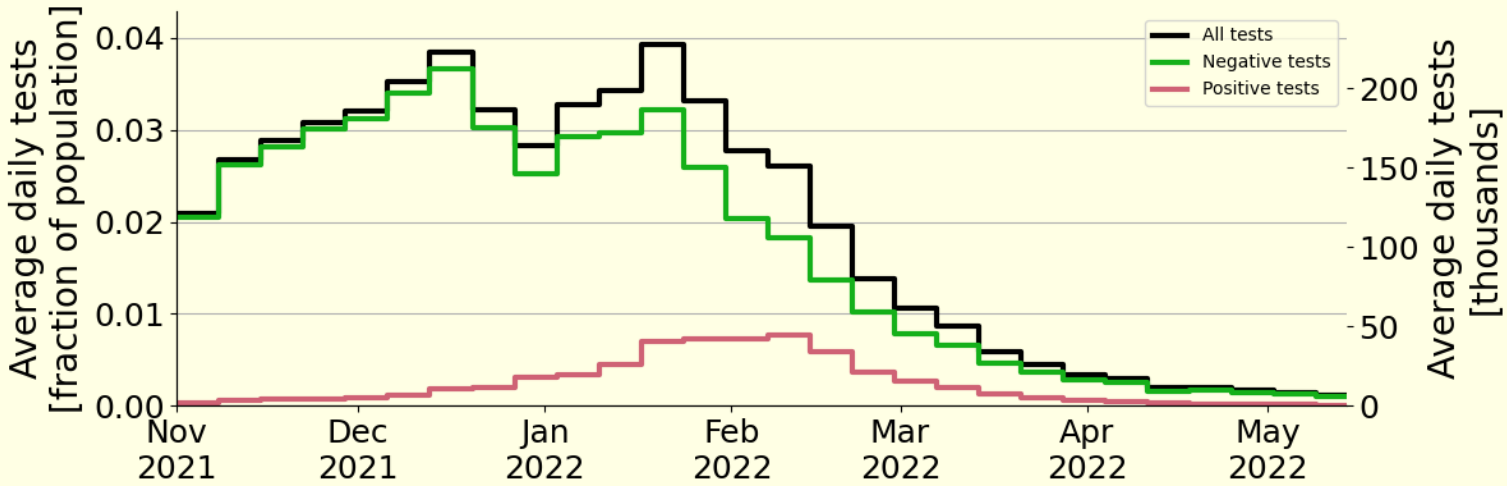
Sum of weekly tests



(Only PCR shown, Antigen-tests at similar magnitude)

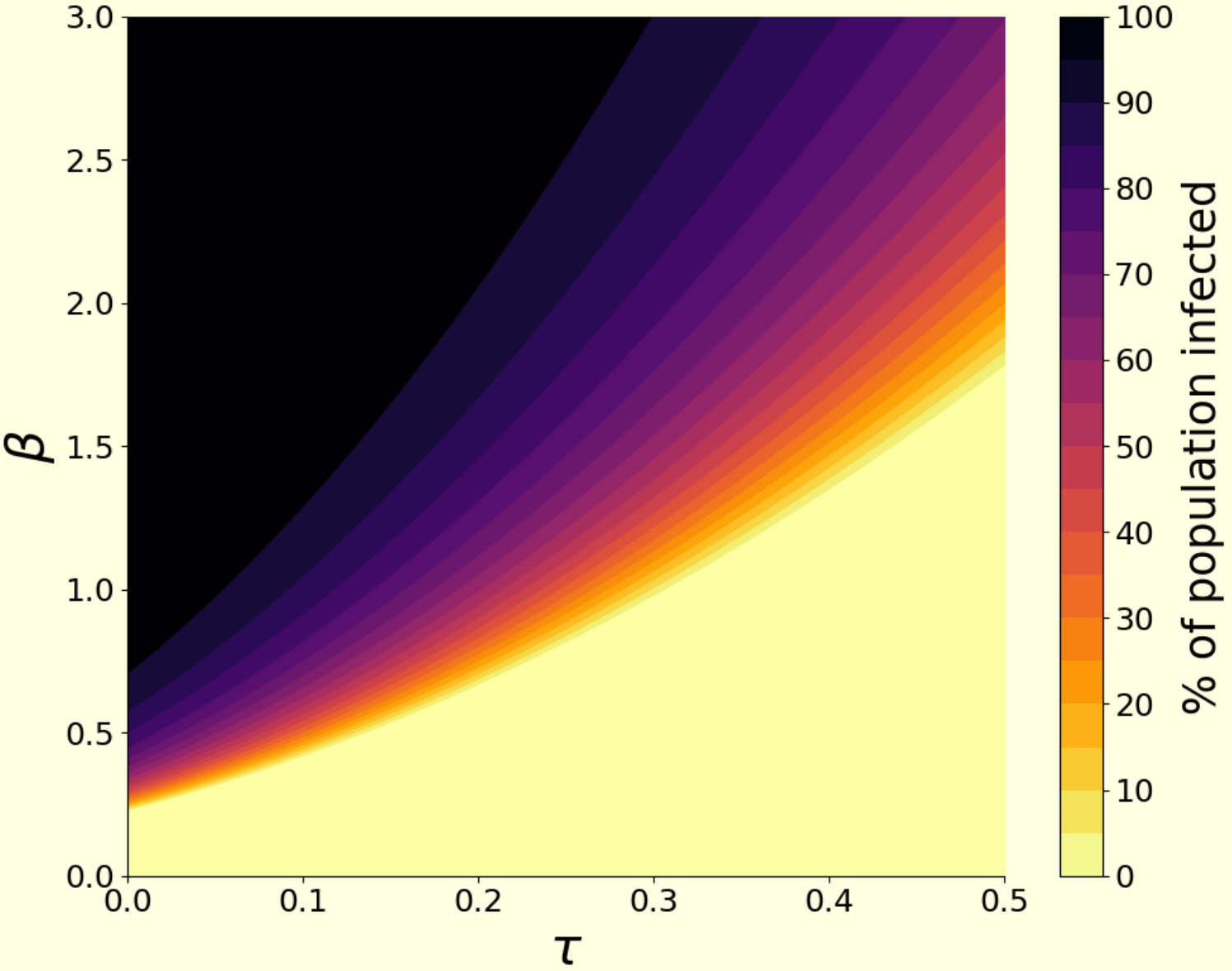
The Danish data

Sum of weekly tests



Scaled to tests per population per day (i.e. τ)

Relating to data



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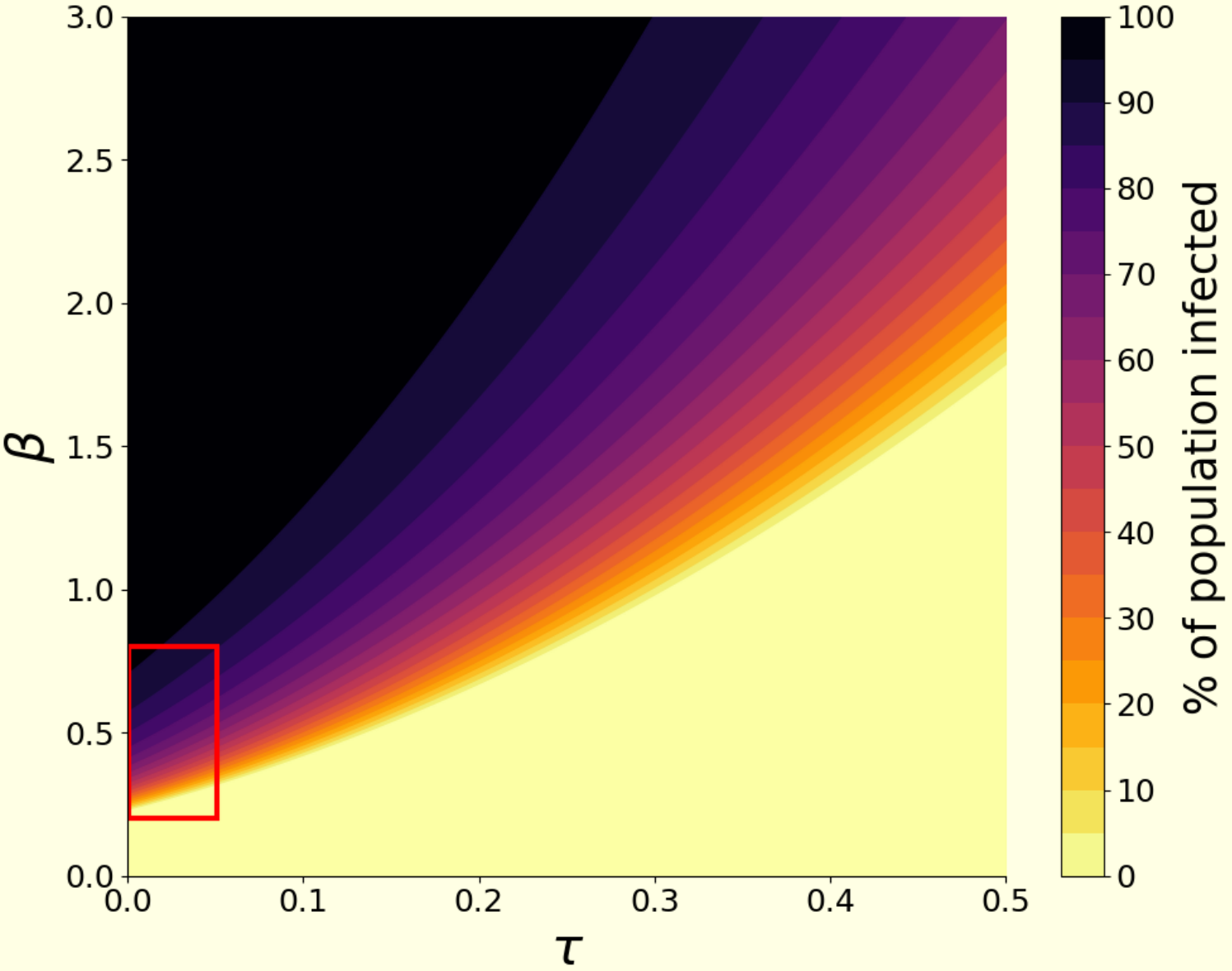

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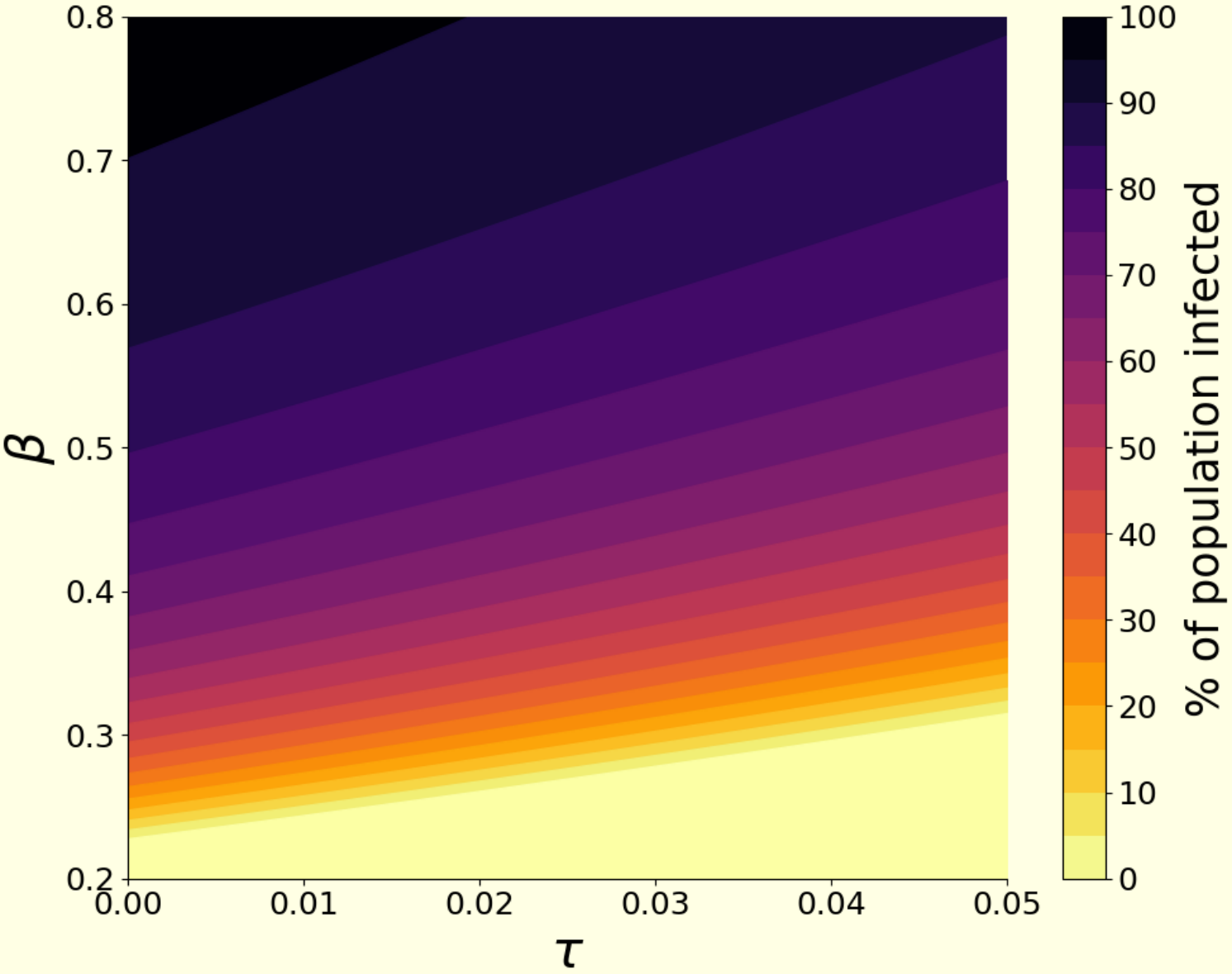

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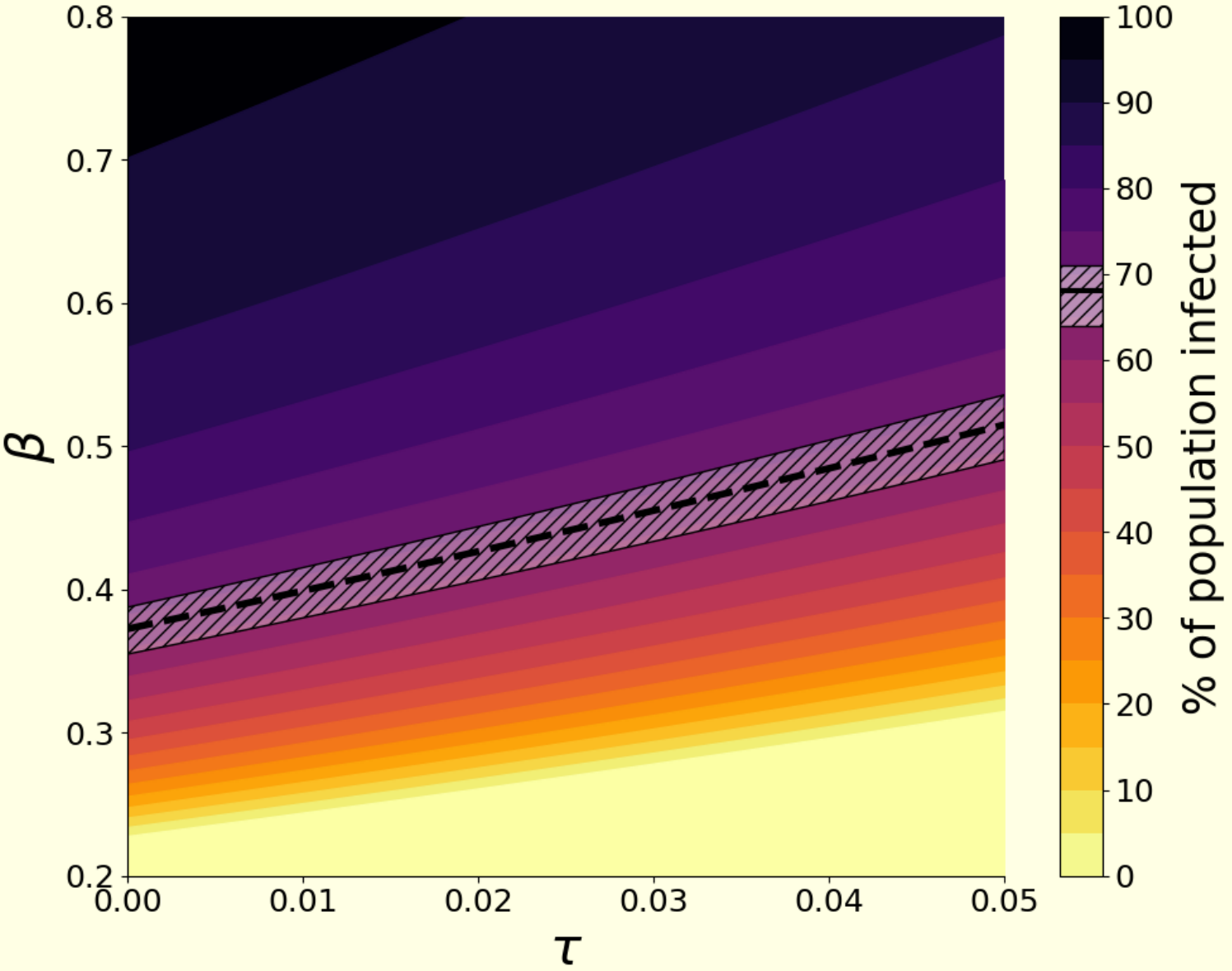

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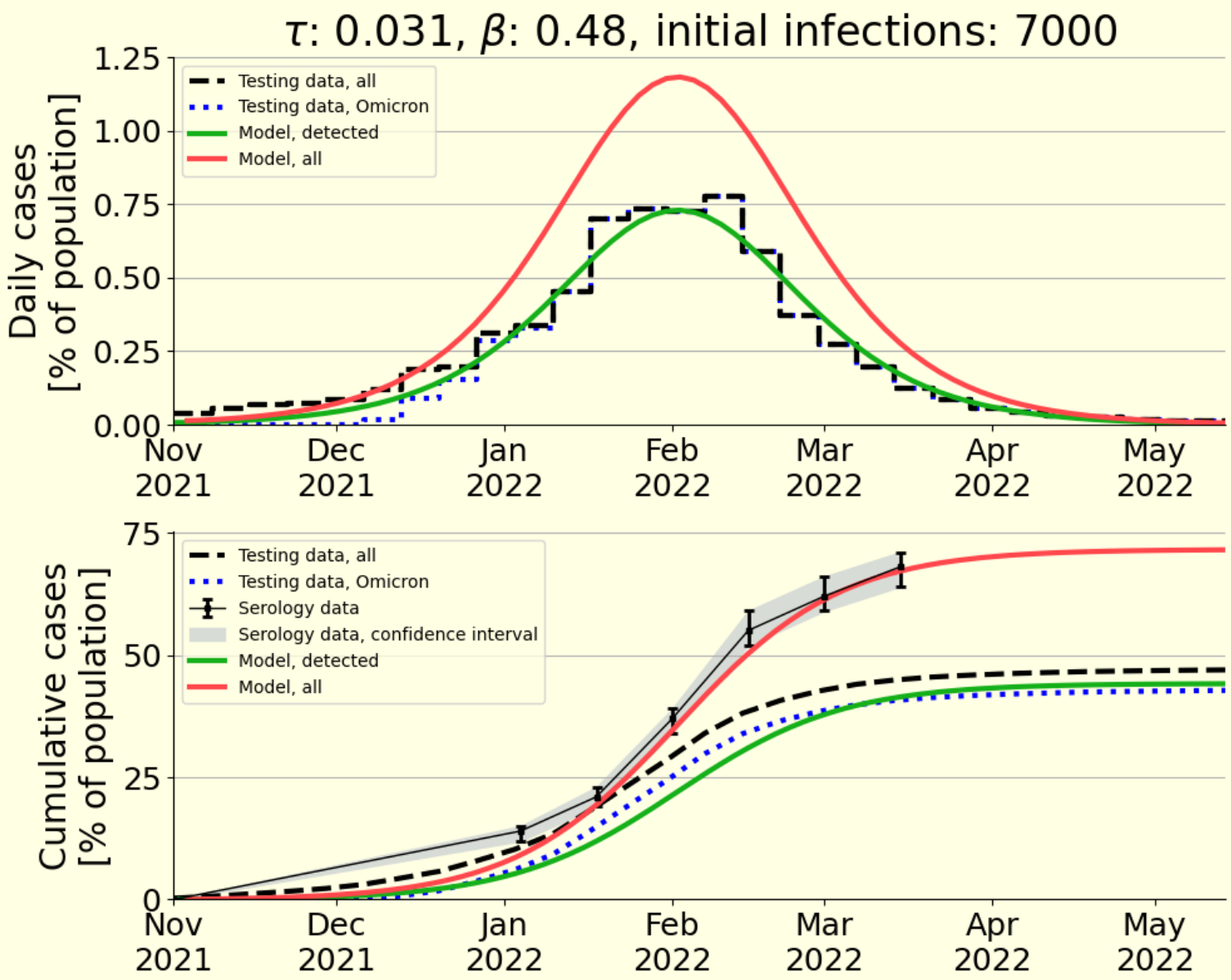

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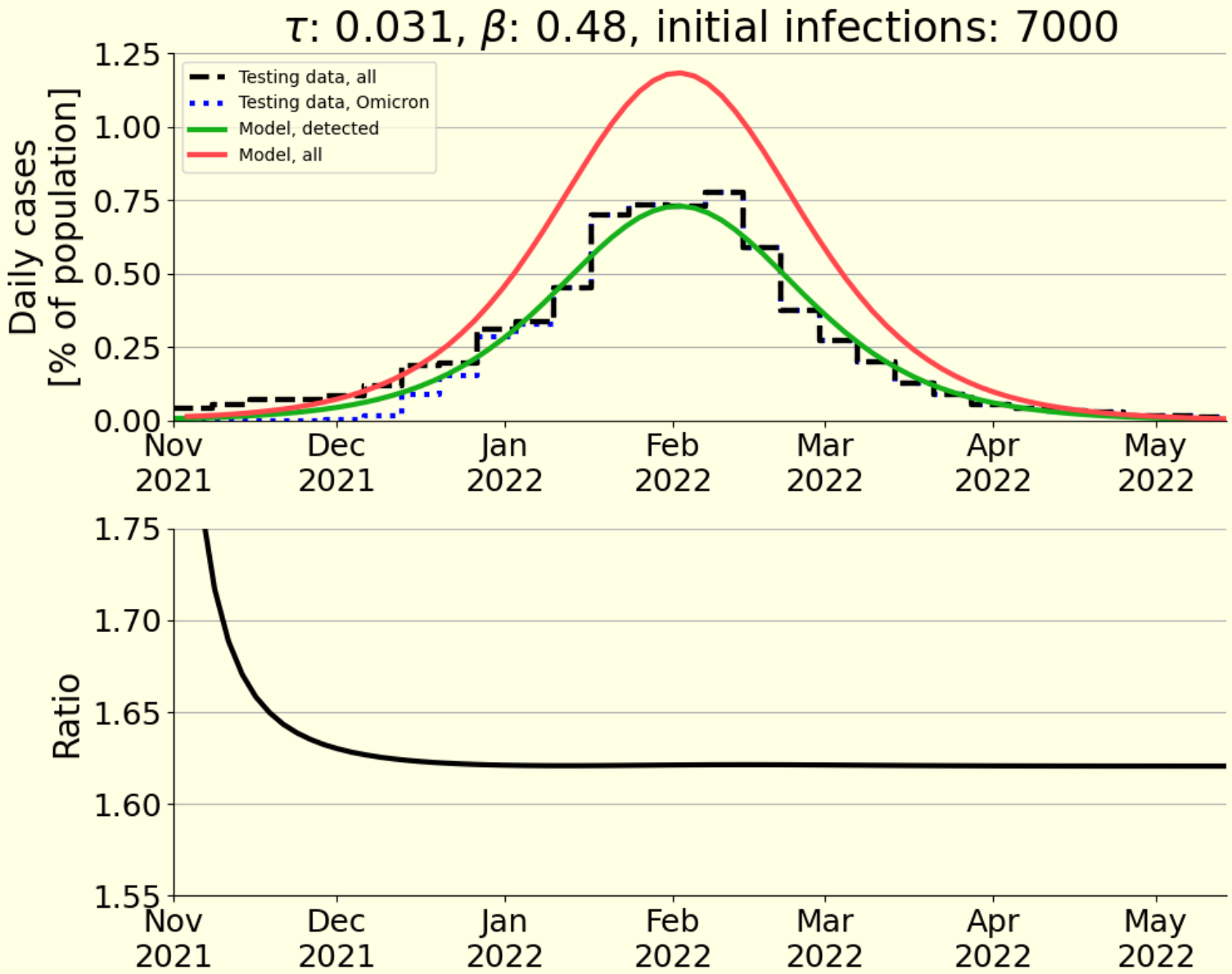

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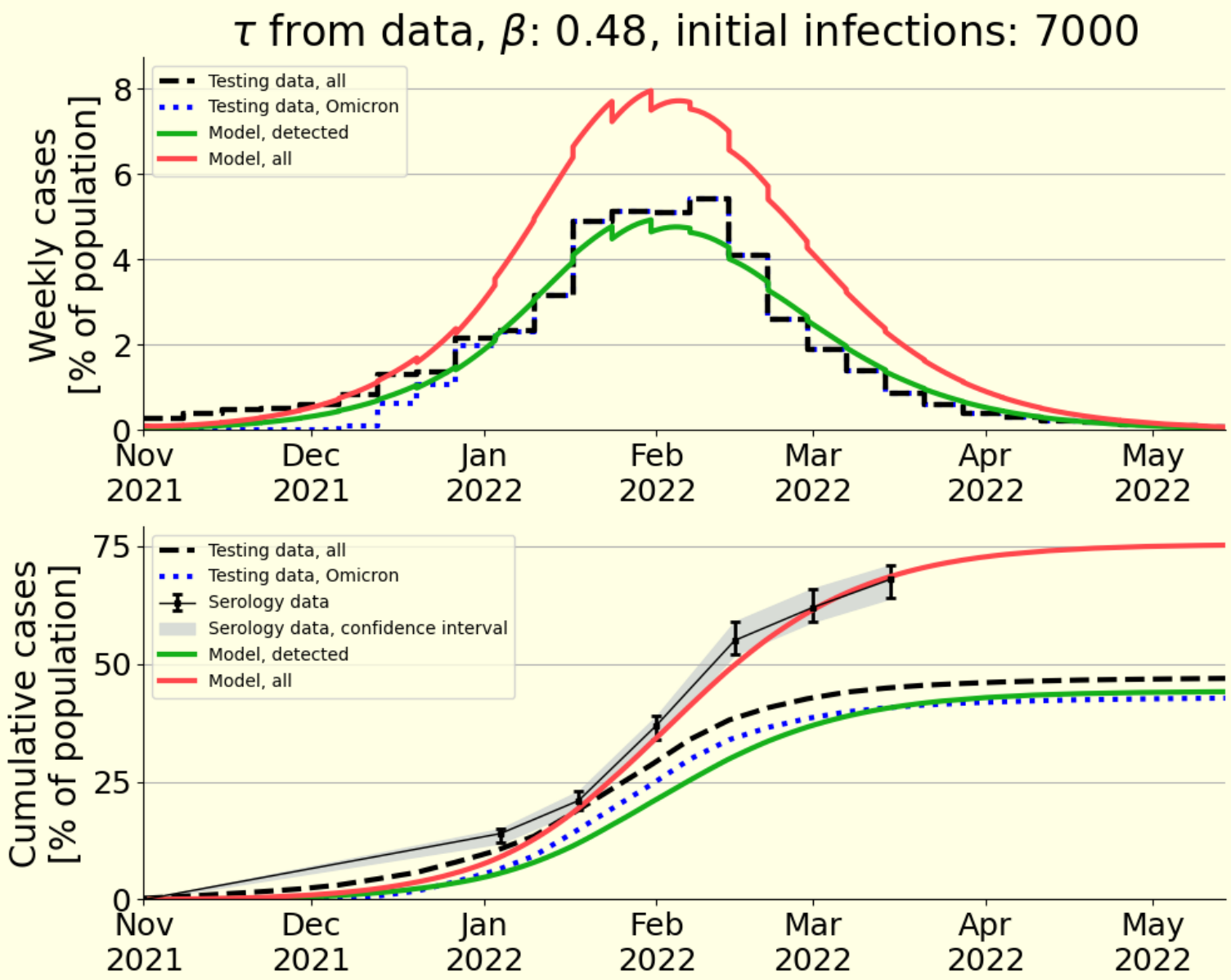

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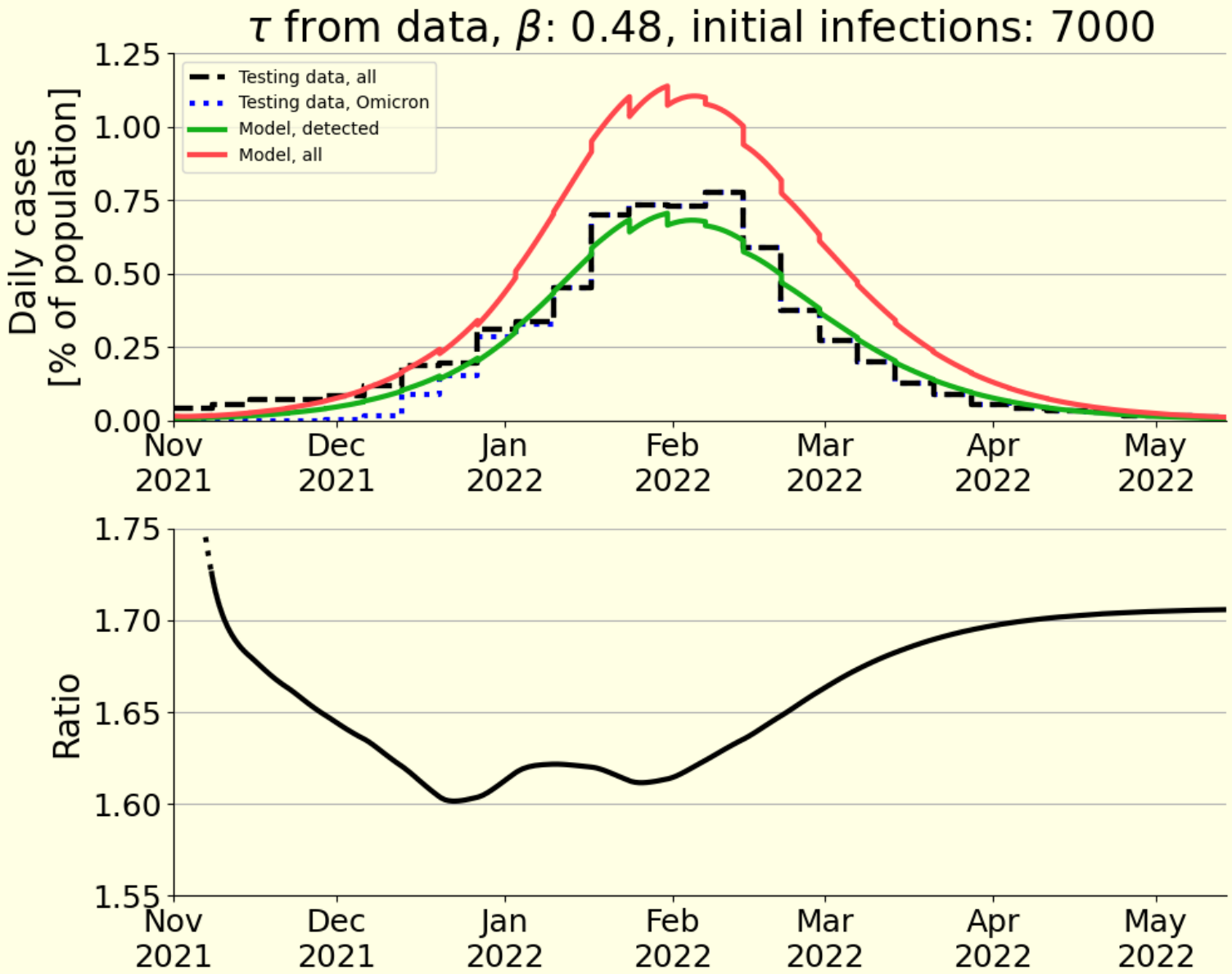

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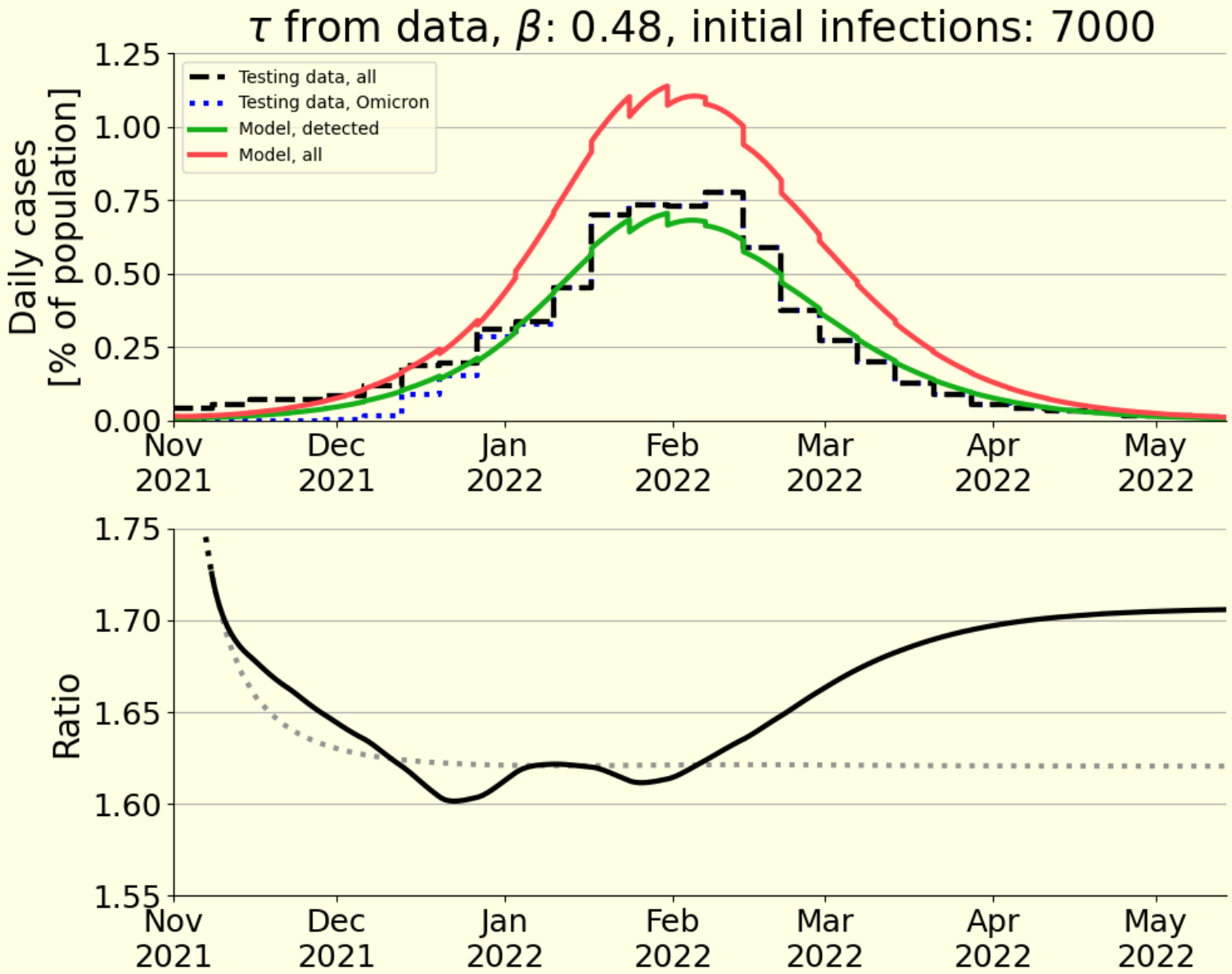

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- For comparing the impact of COVID-19 between countries, accurate estimates of final size are necesssary, particular when evaluating mitigation strategies.

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- For comparing the impact of COVID-19 between countries, accurate estimates of final size are necesssary, particular when evaluating mitigation strategies.
- Using an extended SIR-model, we are able to estimate the fraction of COVID-19 cases identified in the Omicron wave of early 2021 in Denmark.

Discussion and comments

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- The simple model allows for analytical results about the epidemic final size in addition to simulations.

Discussion and comments

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- Using an extended SIR-model, we are able to estimate the fraction of COVID-19 cases identified in the Omicron wave of early 2021 in Denmark.
- The simple model allows for analytical results about the epidemic final size in addition to simulations.
- Results suggest between 58% and 63% were identified, a little lower than official estimates suggesting two-thirds.

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- For comparing the impact of COVID-19 between countries, accurate estimates of final size are necesssary, particular when evaluating mitigation strategies.
- Using an extended SIR-model, we are able to estimate the fraction of COVID-19 cases identified in the Omicron wave of early 2021 in Denmark.
- The simple model allows for analytical results about the epidemic final size in addition to simulations.
- Results suggest between 58% and 63% were identified, a little lower than official estimates suggesting two-thirds.
- Future work consists of further analysis, parameter-fitting and application to other countries.

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Thank you for your attention.

Any questions?

Feel free to also contact me with questions or comments later

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