

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

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- Different approaches to COVID-19 mitigation throughout the world

# Introduction to the problem

- ▶ Different approaches to COVID-19 mitigation throughout the world
- ▶ The impact of differences in data-collection must be understood, also for future research.

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- ▶ The role of testing: Confirmation of symptoms, required for various activities or entirely voluntary?

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- ▶ **How do we compare case-counts between periods and places where testing activity was different?**

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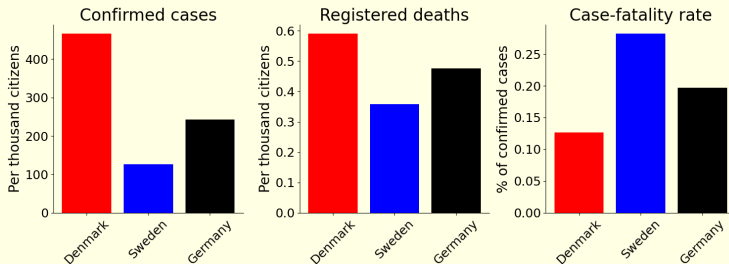
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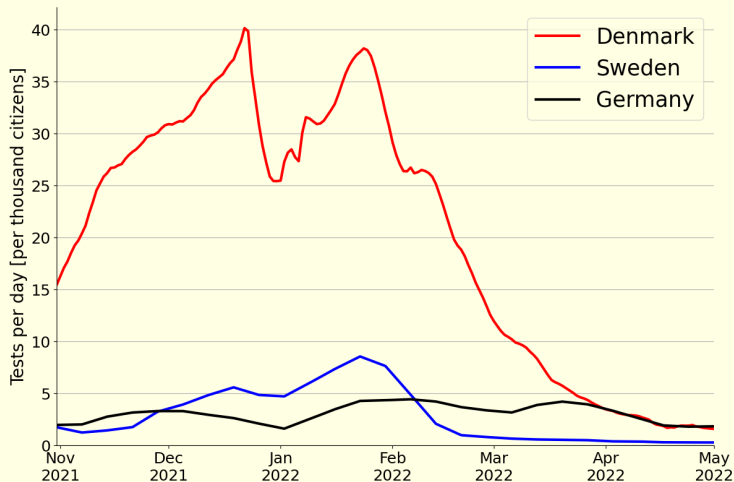
- ▶ Different approaches to COVID-19 mitigation throughout the world
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- ▶ The role of testing: Confirmation of symptoms, required for various activities or entirely voluntary?
- ▶ **How do we compare case-counts between periods and places where testing activity was different?**

Let's look at some data...

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







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

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- ▶ We extend the classic SIR-model to include voluntary testing that identifies pre- and asymptomatic cases.

- ▶ We aim to determine the ratio between observed cases and the total number of COVID-19 cases.
- ▶ This ratio can be used as a correction-factor for observed data.
- ▶ We extend the classic SIR-model to include voluntary testing that identifies pre- and asymptomatic cases.
- ▶ This allows us to investigate the relationship between the rate of voluntary testing and the appropriate correction-factor.

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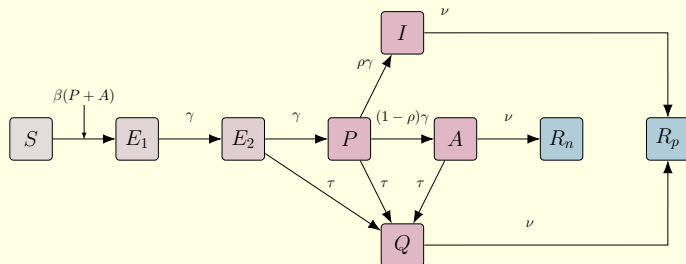
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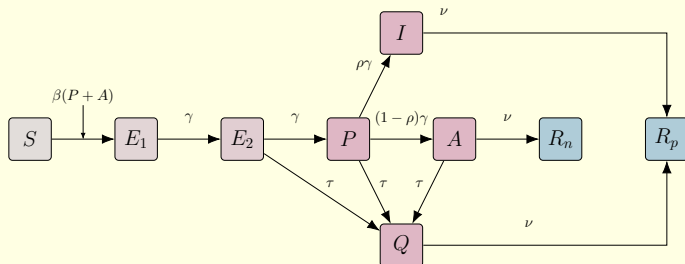
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$$\dot{S} = -\beta S(P + A)$$

$$\dot{E}_1 = \beta S(P + A) - \gamma E_1$$

$$\dot{E}_2 = \gamma E_1 - \gamma E_2 - \tau E_2$$

$$\dot{P} = \gamma E_2 - \gamma P - \tau P$$

$$\dot{I} = \gamma \rho P - \nu I$$

$$\dot{A} = \gamma(1 - \rho)P - \nu A - \tau A$$

$$\dot{Q} = \tau(E_2 + P + A) - \nu Q$$

$$\dot{R}_p = \nu Q + \nu I$$

$$\dot{R}_n = \nu A$$

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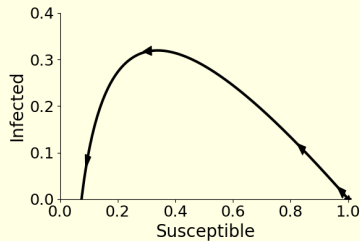
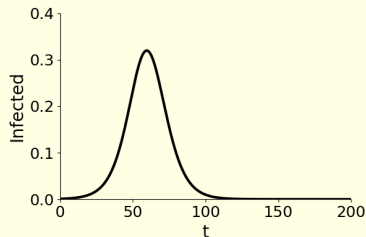
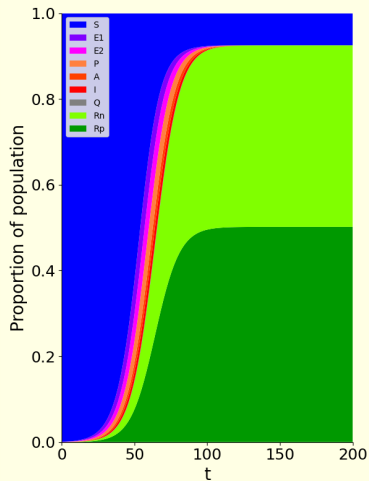
$$\begin{aligned}\dot{S} &= -\beta S(P + A) & \dot{A} &= \gamma(1 - \rho)P - \nu A - \tau A \\ \dot{E}_1 &= \beta S(P + A) - \gamma E_1 & \dot{Q} &= \tau(E_2 + P + A) - \nu Q \\ \dot{E}_2 &= \gamma E_1 - \gamma E_2 - \tau E_2 & \dot{R}_p &= \nu Q + \nu I \\ \dot{P} &= \gamma E_2 - \gamma P - \tau P & \dot{R}_n &= \nu A \\ \dot{I} &= \gamma \rho P - \nu I\end{aligned}$$

<i>Symbol</i>	<i>Description</i>	<i>Default value</i>
$\beta$	Infectivity	2/3
$\nu$	Rate of recovery	1/3
$\gamma$	Rate of disease progression	1/3
$\rho$	Fraction of symptomatic cases	1/2
$\tau$	Rate of testing	0 to 0.5

All rates units of day<sup>-1</sup>. Approximate  $R_0$  of 1.4 initially.



## General dynamics like classic SIR-model.



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# Analysis of fraction of cases identified

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We consider the fraction of cases identified:

$$K = \frac{r_p}{r_p + r_n} \quad (1)$$

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

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The correction-factor we want is  $K^{-1}$ .

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Through the methods previously applied in (Andreasen, 2018), we are able to analytically determine:

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

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Note that  $K$  is independent of  $\beta$ .

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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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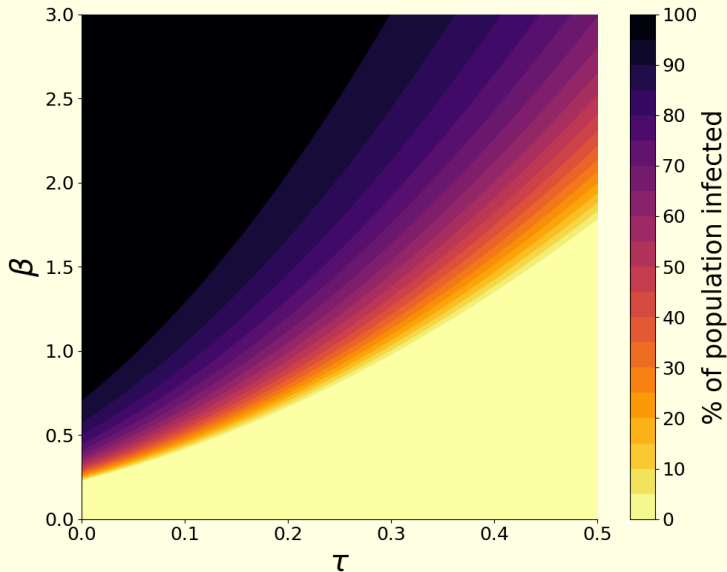
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Although the fraction of cases identified,  $K$ , is independent of  $\beta$ , the epidemic final size, i.e.  $r_n + r_p$ , is not.

Let us take a look at the final size as a function of  $\tau$  and  $\beta$ .

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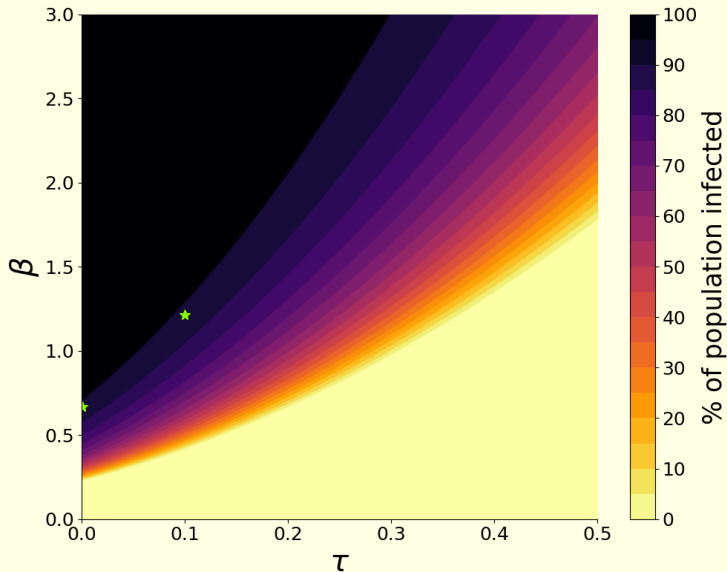
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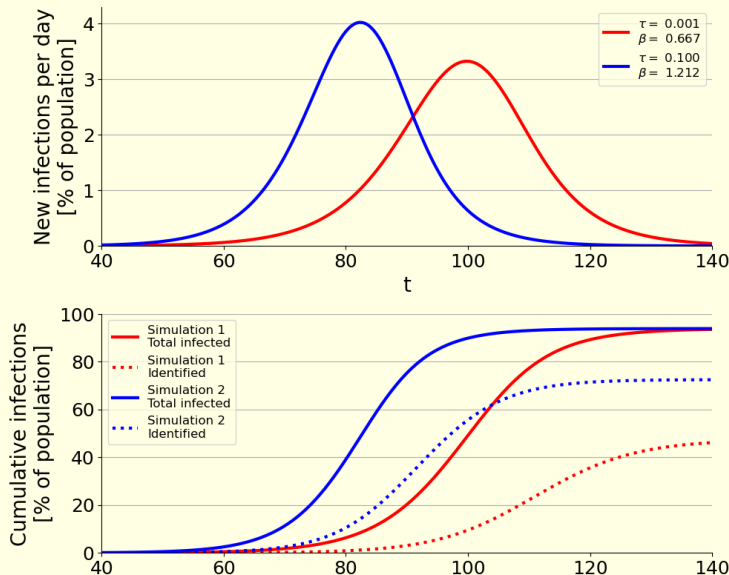
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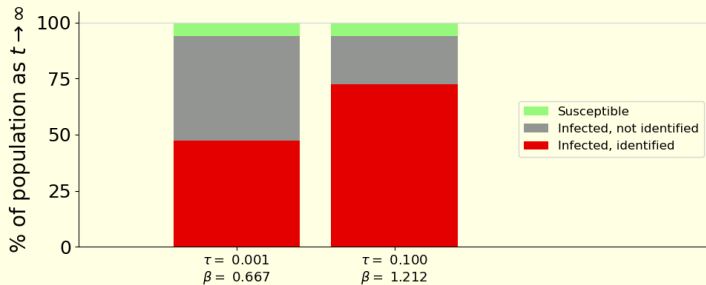
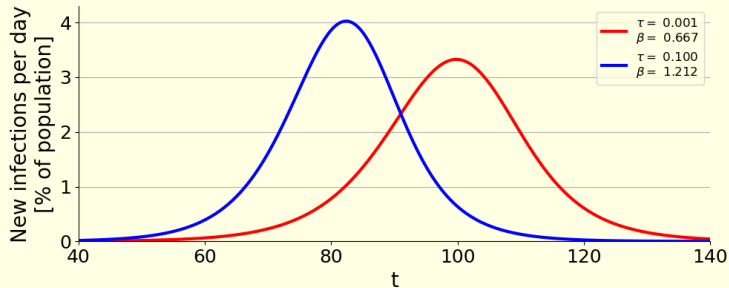
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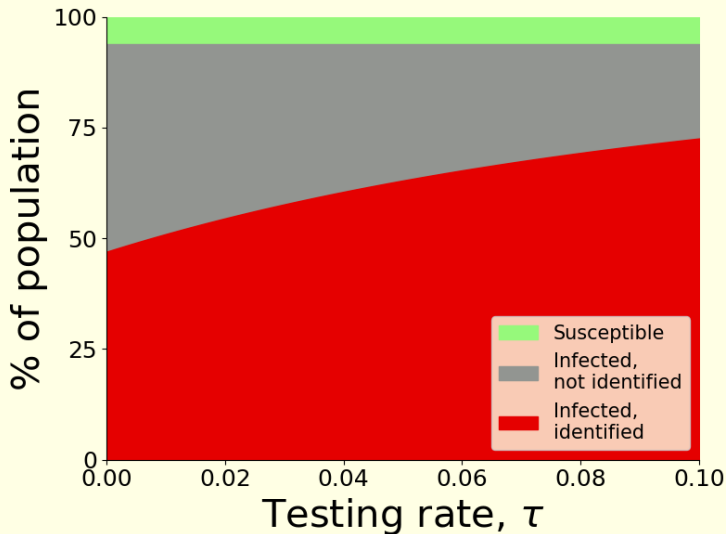
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( $\beta$  chosen such that final size is fixed)

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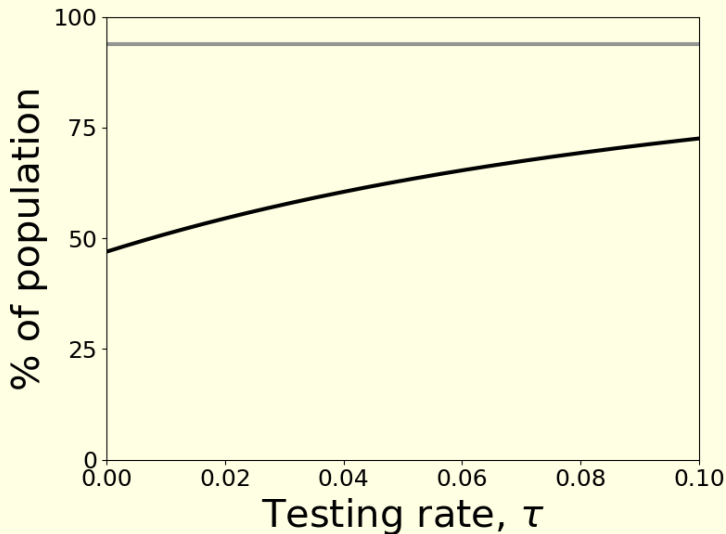
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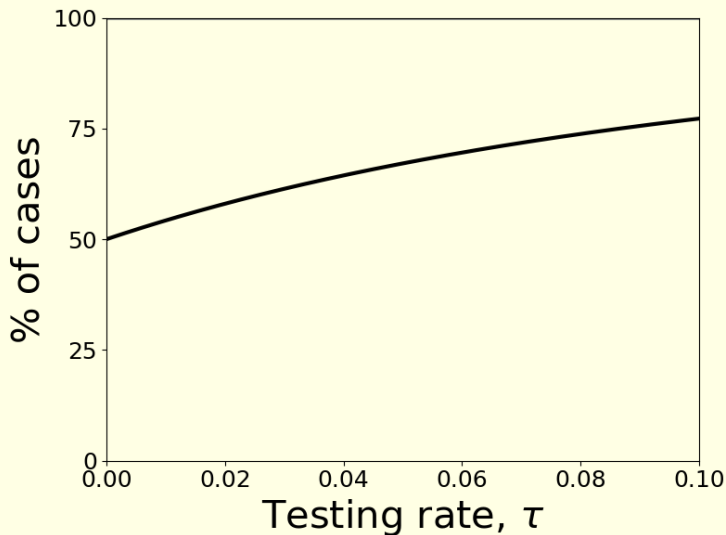
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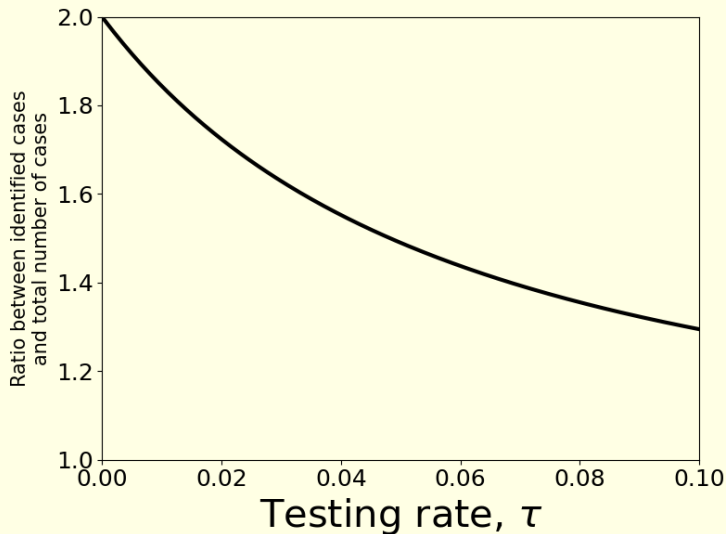
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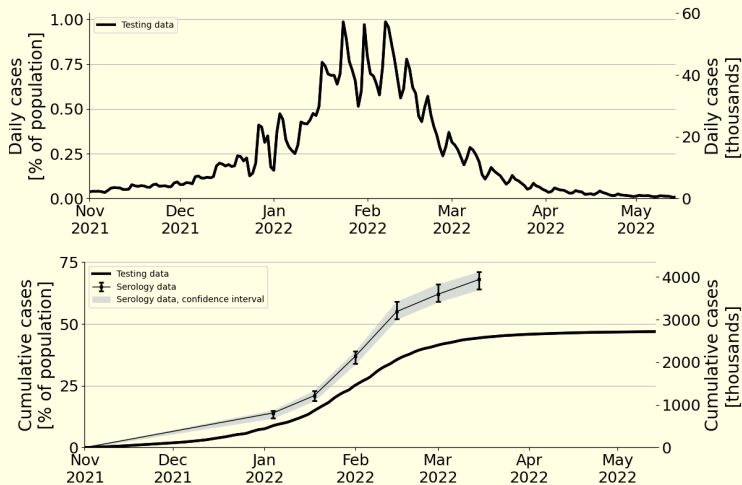
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## Daily cases and serology from blood-donors



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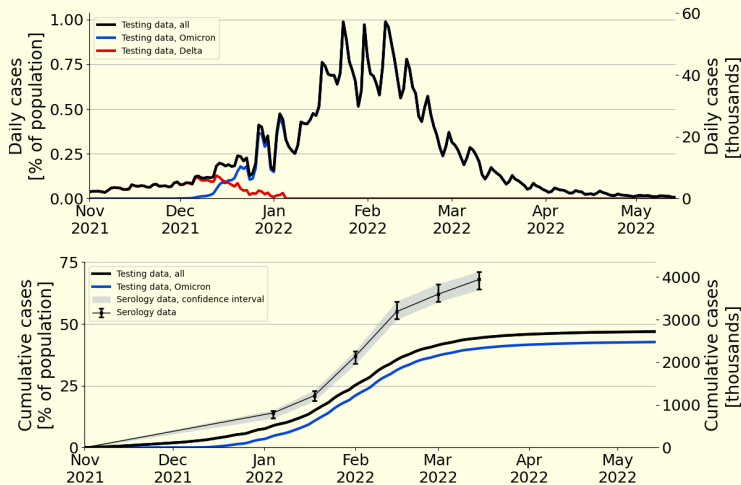
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December 2021: Variant-sampling of 80 to 90% of cases.

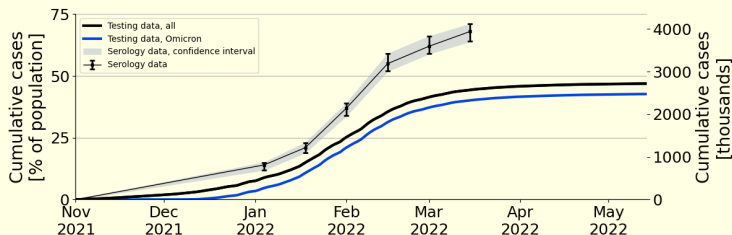
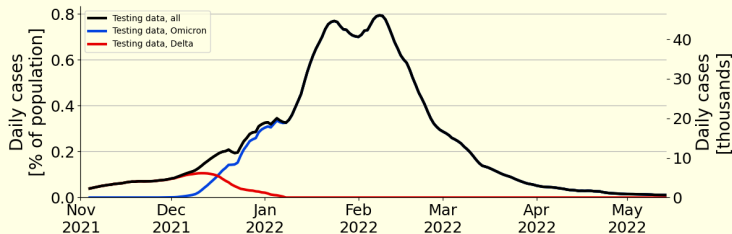


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Smoothing: 7-day running mean.



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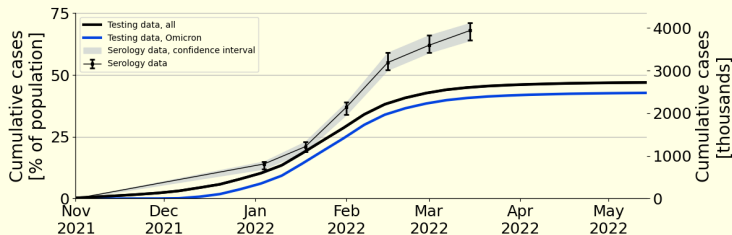
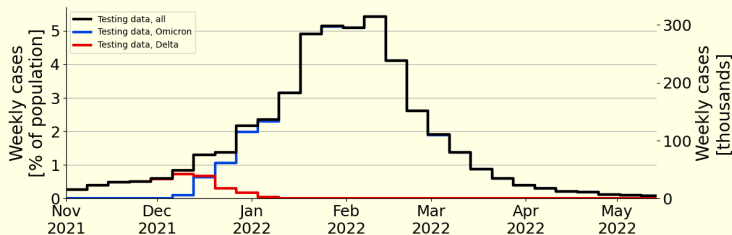
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## Weekly sums (Monday to Sunday)



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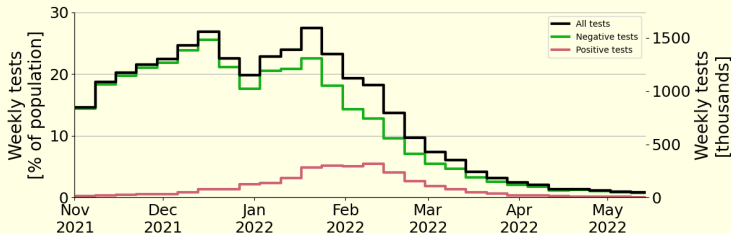
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## Sum of weekly tests



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

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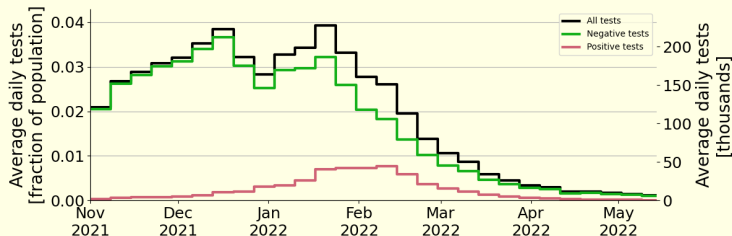
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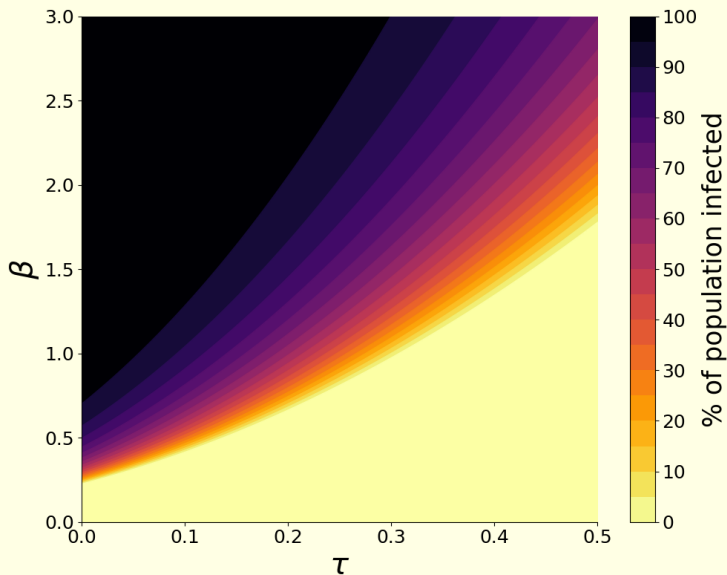
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## Sum of weekly tests



Scaled to tests per population per day (i.e.  $\tau$ )

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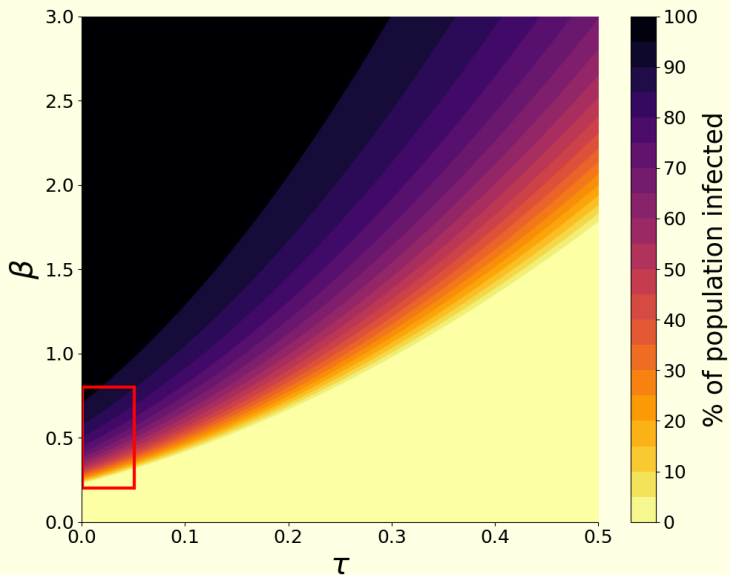
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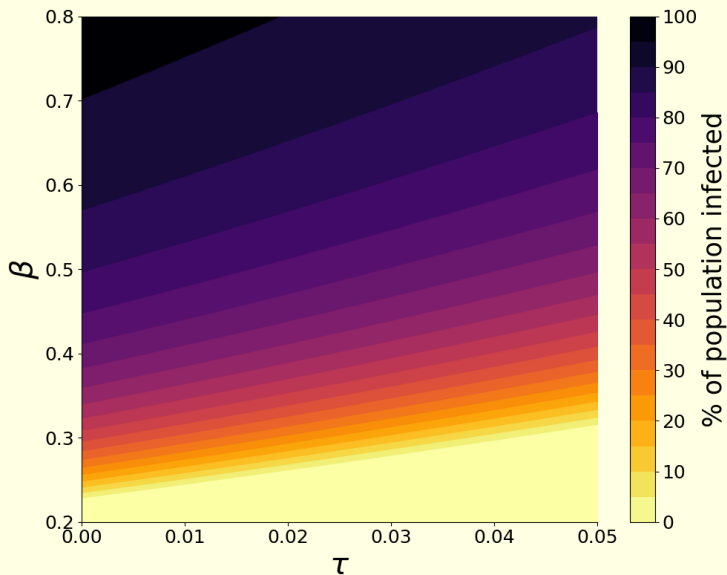
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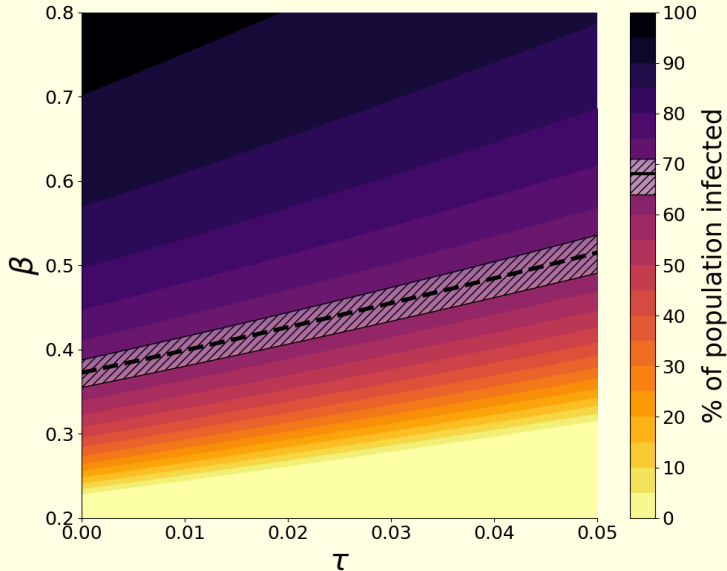
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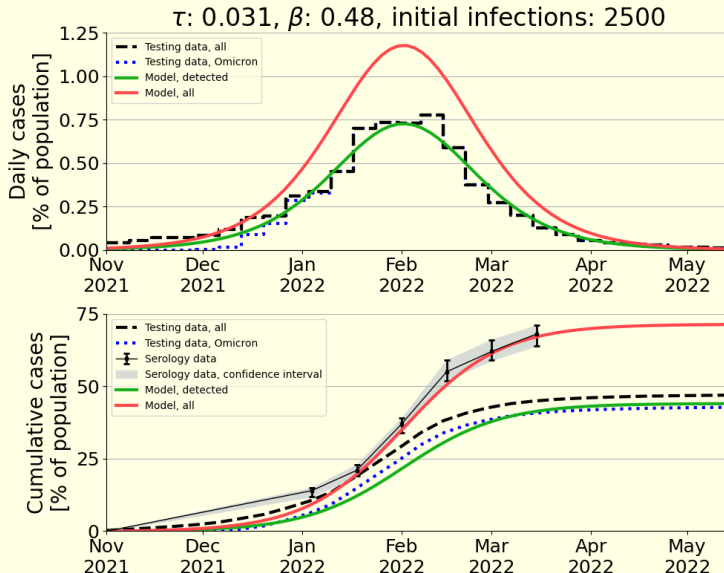
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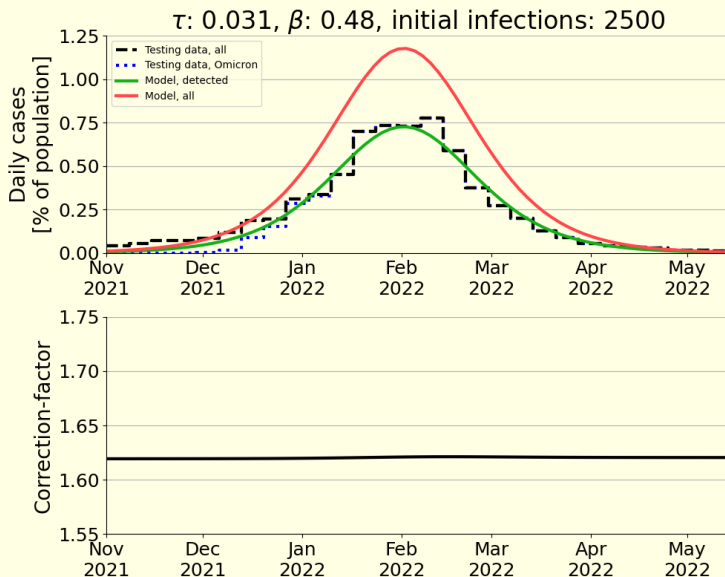
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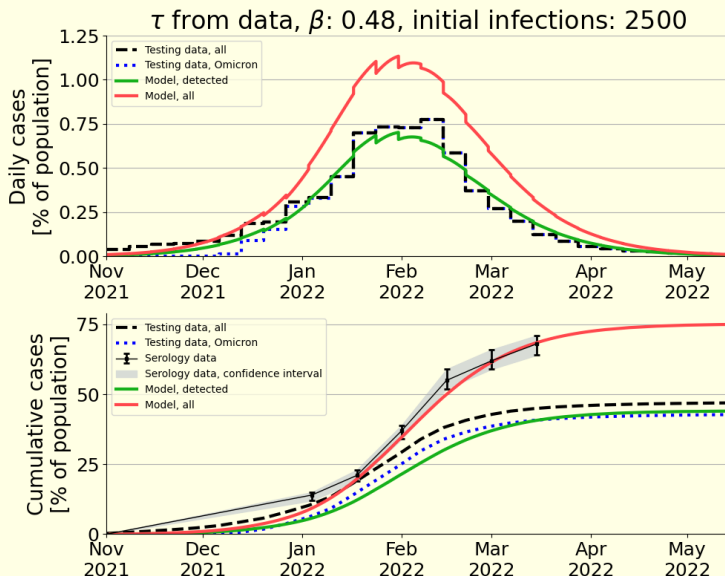
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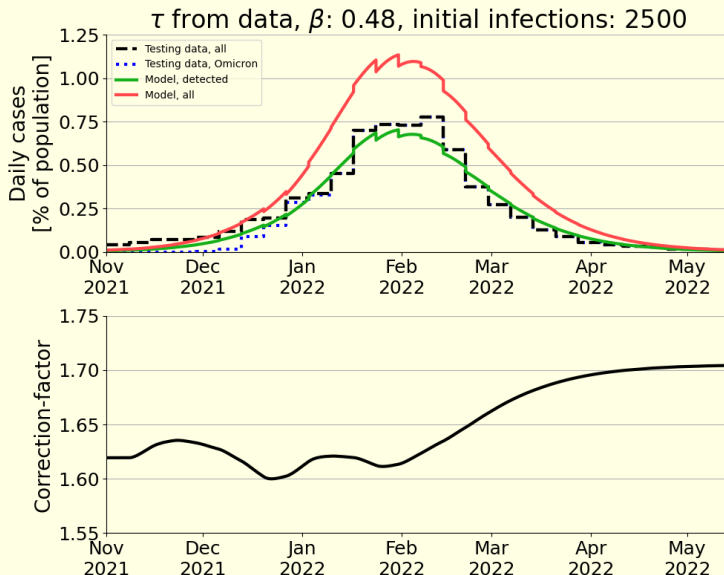
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Fraction identified

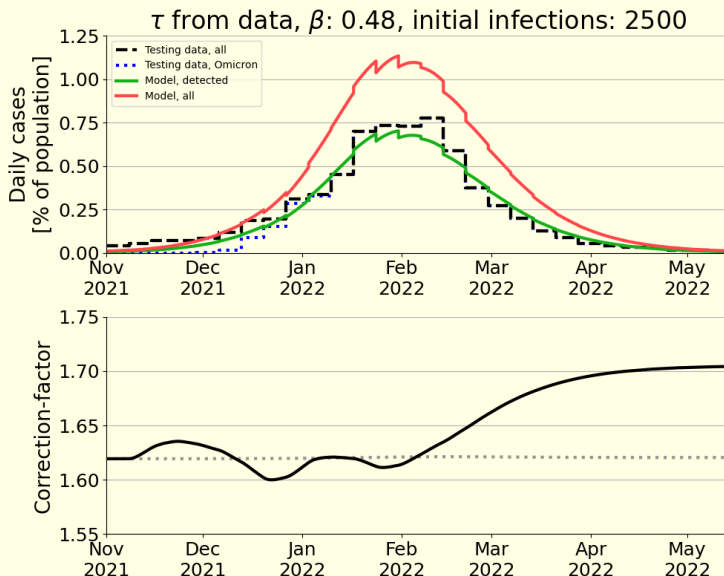
Fixed final size

## Data and simulations

The data

Relating to data

## Discussion



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- ▶ 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.

# Thank you for your attention.

## Any questions?



Feel free to also contact me  
with questions or comments  
later

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Determining  
COVID incidence

Pedersen, Berrig &  
Andreasen

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The problematic

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