

Semiparametric SIRD model

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key questions

- ▶ how SIRD parameters evolve over time?
- ▶ how to deal with seasonality in official reports?
- ▶ how to deal with under-reporting?
- ▶ what about cross-transmission rates?

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 - ▶ active cases vs recovered data
 - ▶ excess deaths handles lack of testing, but not asymptomatics
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 - ▶ kernel nonlinear least squares to impose positivity constraints

time-varying parameters

let $k_{\tau,t} \equiv K\left(\frac{t-\tau}{h}\right)$, with $h \propto T^{-n}$

$$\Delta D_{t+1} = \mu_t I_t \Rightarrow \hat{\mu}_t = \left(\sum_{\tau=1}^{t-1} k_{\tau,t} I_{\tau}^2 \right)^{-1} \sum_{\tau=1}^{t-1} k_{\tau,t} I_{\tau} \Delta D_{\tau+1}$$

$$\Delta R_{t+1} = \nu_t I_t \Rightarrow \hat{\nu}_t = \left(\sum_{\tau=1}^{t-1} k_{\tau,t} I_{\tau}^2 \right)^{-1} \sum_{\tau=1}^{t-1} k_{\tau,t} I_{\tau} \Delta R_{\tau+1}$$

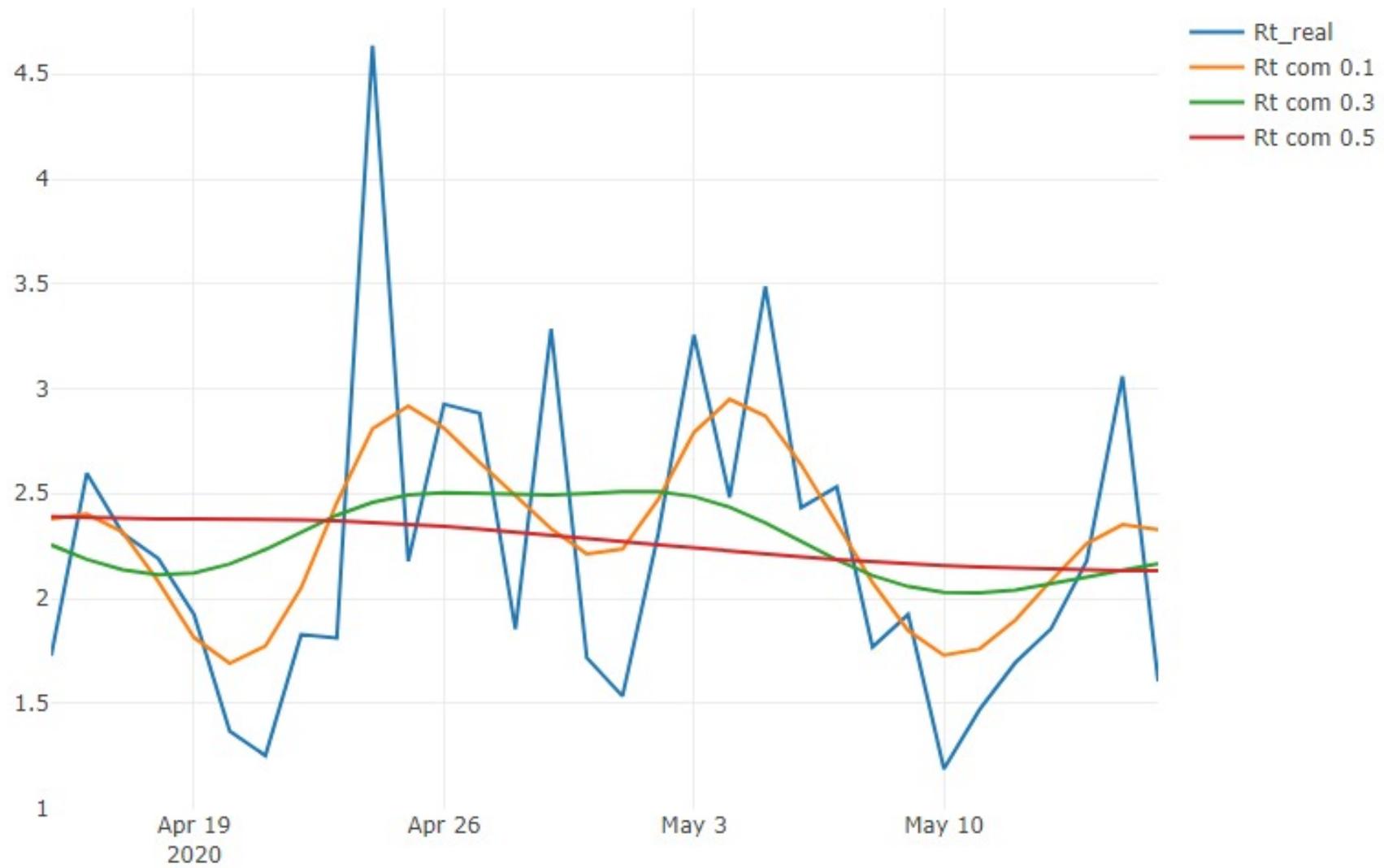
$$\Delta S_{t+1} = \beta_t S_t I_t \Rightarrow \hat{\beta}_t = \left(\sum_{\tau=1}^{t-1} k_{\tau,t} S_{\tau}^2 I_{\tau}^2 \right)^{-1} \sum_{\tau=1}^{t-1} k_{\tau,t} S_{\tau} I_{\tau} \Delta S_{\tau+1}$$

$$R_e(t) = \frac{\beta_t}{\mu_t + \nu_t} \Rightarrow \hat{R}_e(t) = \frac{\hat{\beta}_t}{\hat{\mu}_t + \hat{\nu}_t}$$

- ▶ one-step estimators that are consistent and asymptotically normal

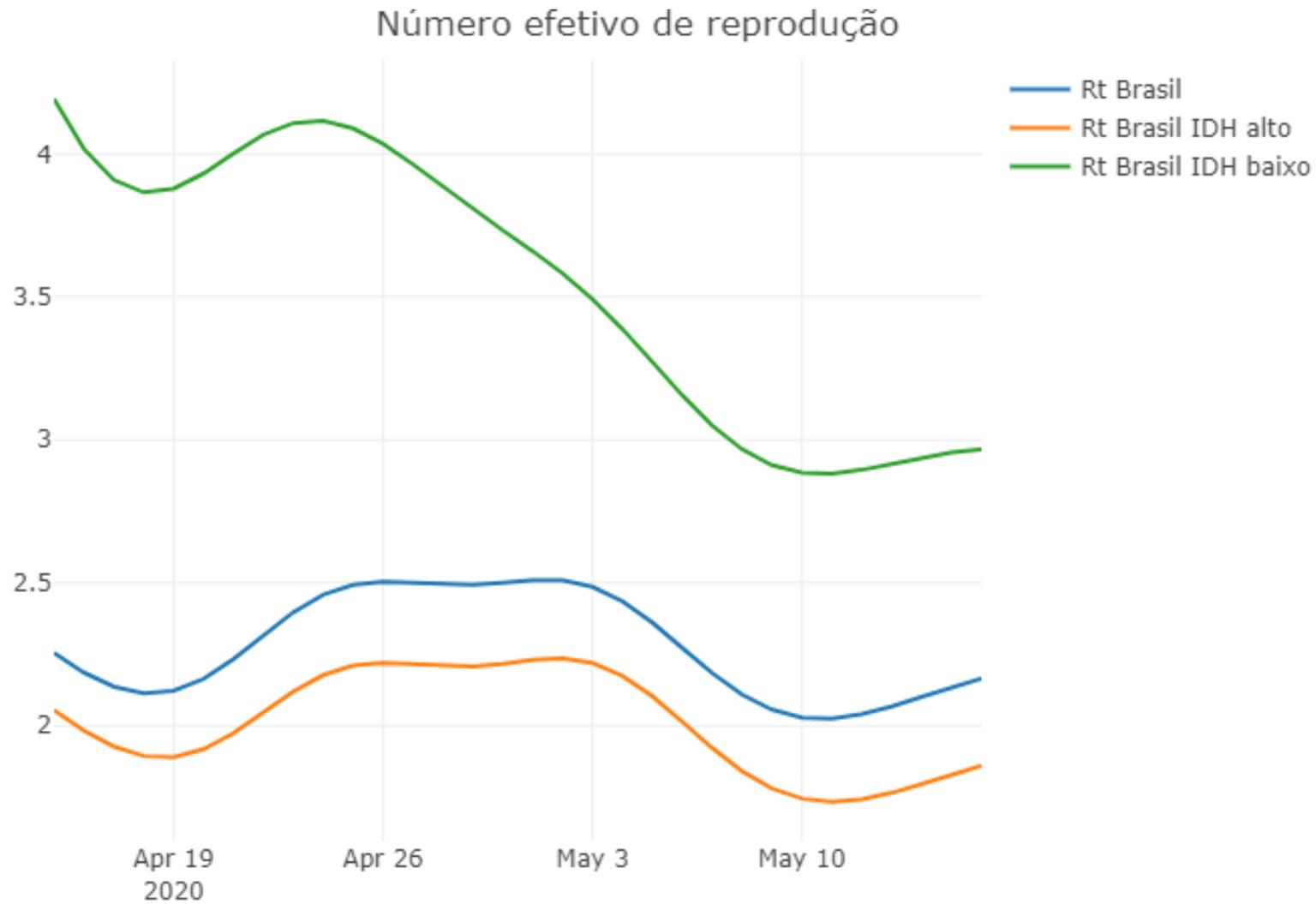
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smoothing

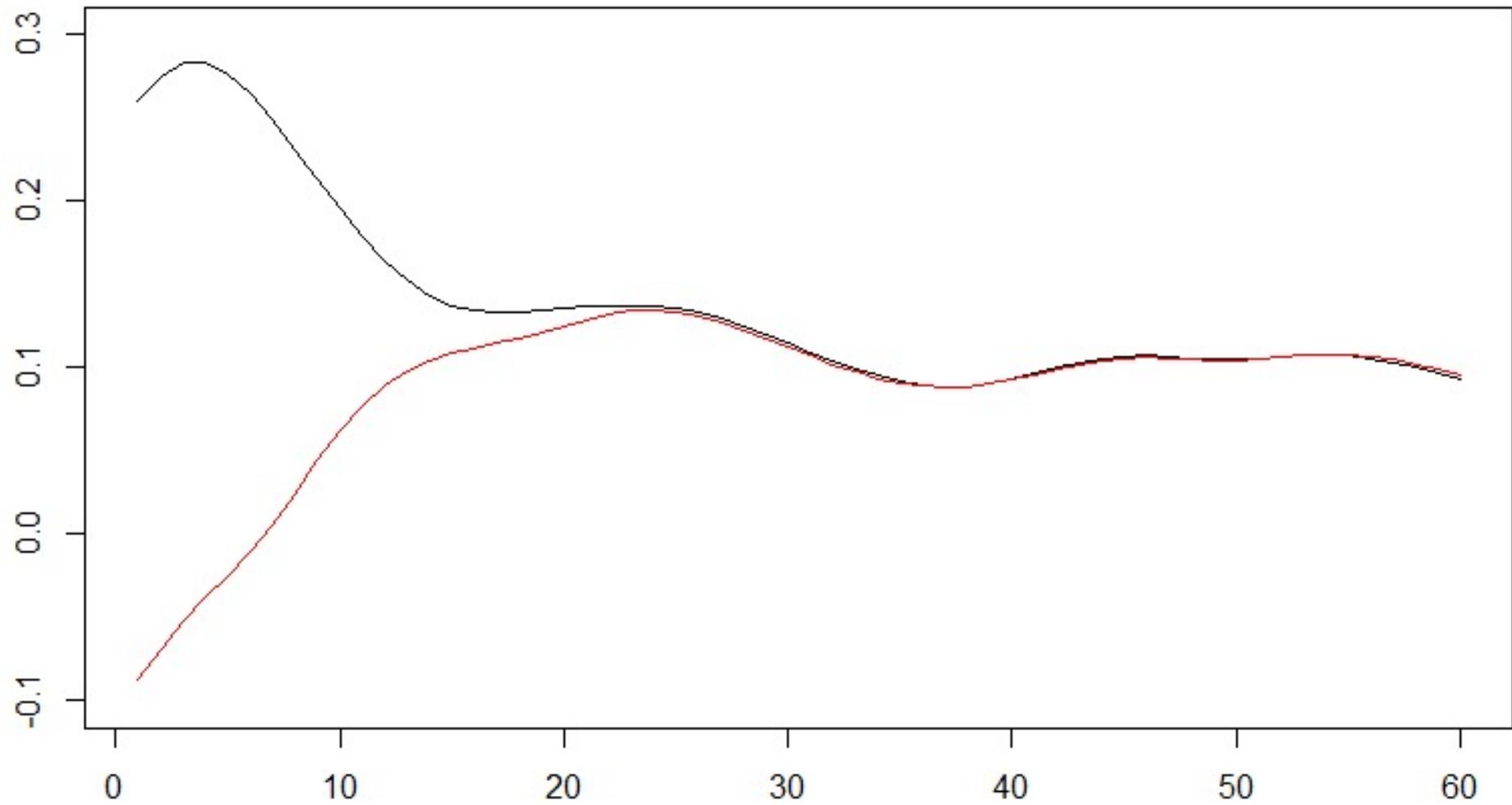


effective reproduction number

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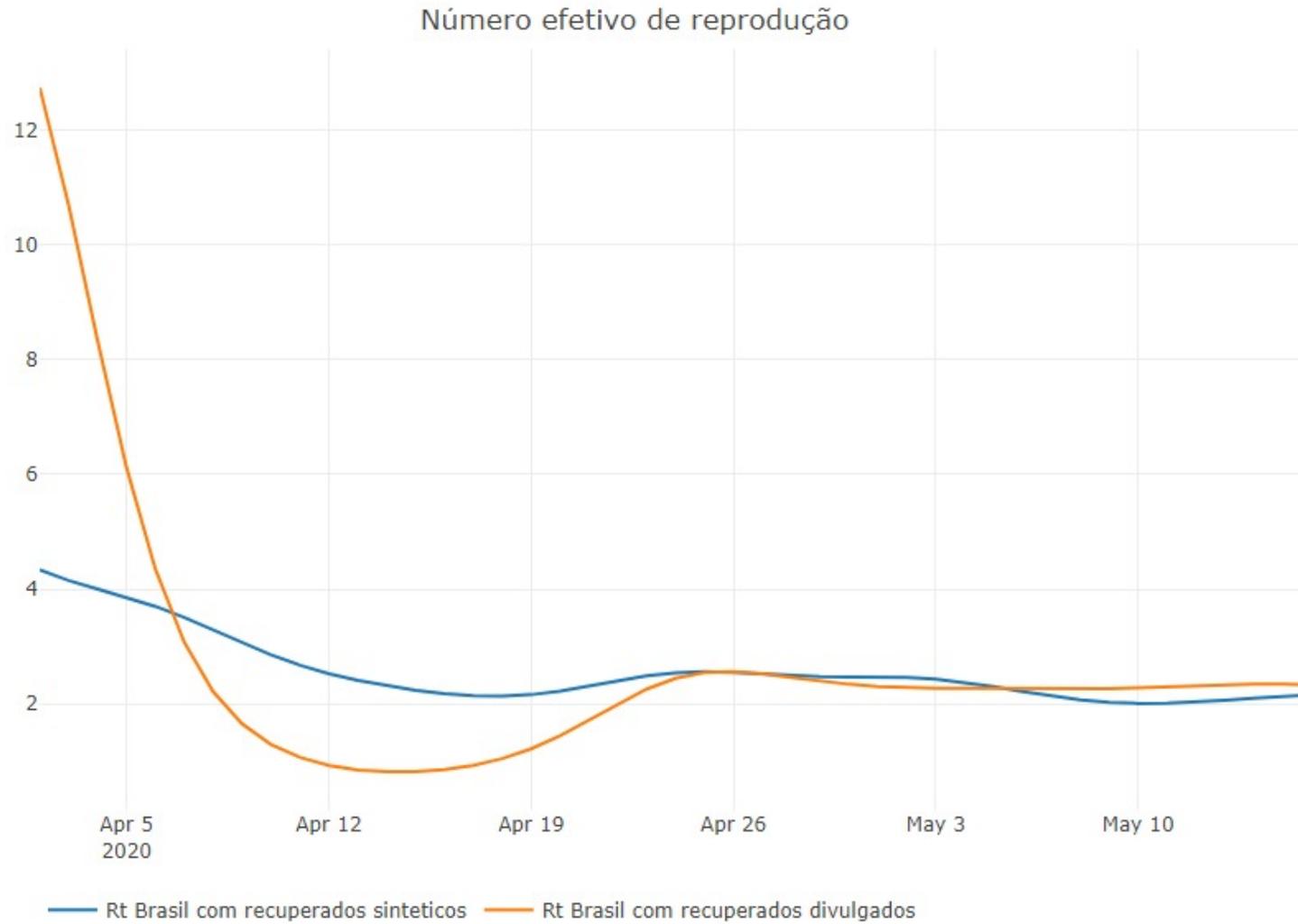


seasonality

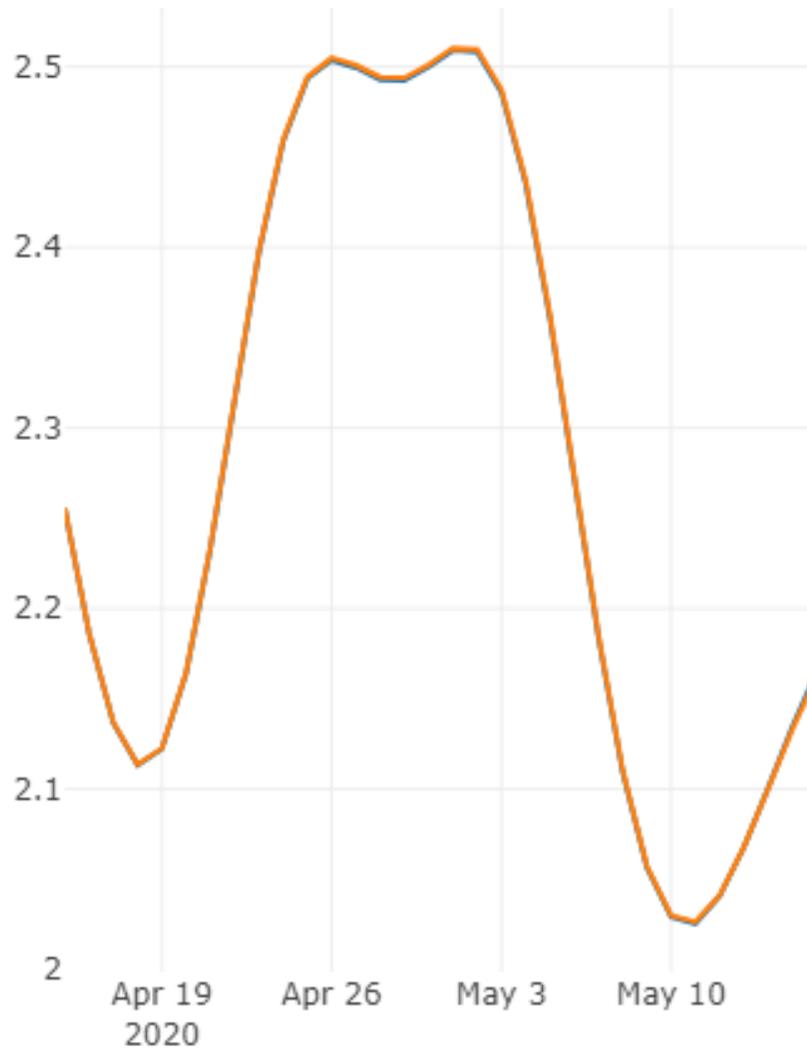


data quality

active cases



data quality



underreporting

deaths $\sim 2.5\times$ official number
cases $\sim 10\times$ official number

- ▶ gathering excess deaths to have time-varying underreporting rates

cross-transmission...

... between different age groups

- ▶ < 40 , $40-60$, > 60

... cross-transmission between different cities

- ▶ Rio de Janeiro vs Periphery
- ▶ São Paulo vs Periphery
- ▶ Vitória vs Vila Velha
- ▶ 'morro' vs 'asfalto'

▶ how to impose positivity constraints?

- ▶ kernel nonlinear least squares
- ▶ wavelet approach