COVID-19 in Slovenia, from a success story to disaster: What lessons can be learned?

Damjan Manevski[1], Rok Blagus[1,2,3], Nina Ružić Gorenjec[1], Nataša Kejžar[1], Maja Pohar Perme[1], Bor Vratanar[1]

[1]IBMI, Medicinska fakulteta, Univerza v Ljubljani
[2]Fakulteta za šport, Univerza v Ljubljani
[3]FAMNIT, Univerza na Primorskem

21. 9. 2021

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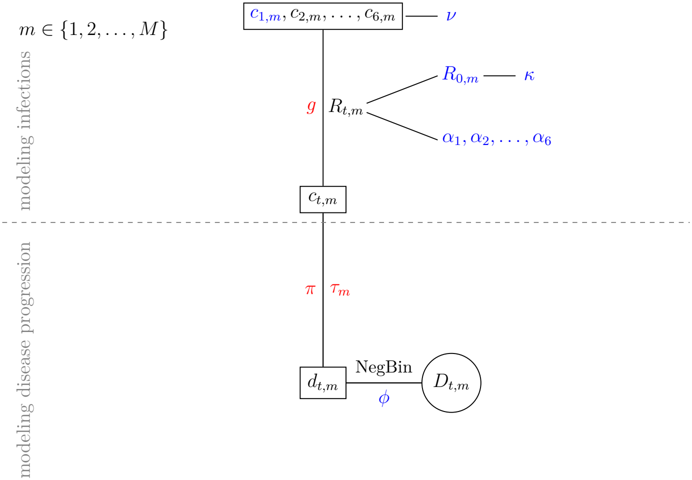
(5) Why is contact tracing so important?

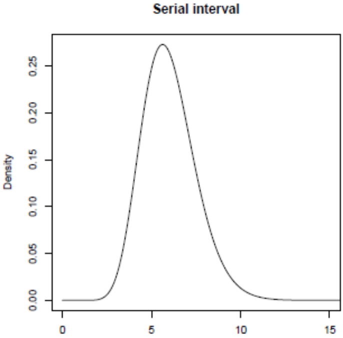
Do we need non-pharmaceutical interventions?

Model Flaxman et al. (Nature, 2020), Manevski et al. (ZV, 2020)



$$c_{t,m} = \left(1 - \frac{\sum_{k=1}^{t-1} c_{k,m}}{N_m}\right) R_{t,m} \sum_{k=0}^{t-1} c_{k,m} g_{t-k}$$

$$g_1 = \int_0^{1.5} g(t)dt, \quad g_s = \int_{s-0.5}^{s+0.5} g(t)dt,\ s = 2, 3, \ldots$$



$$R_{t,m} = R_{0,m} \exp\left(\sum_{l=1}^{6} (-\alpha_l) I_{l,t,m}\right)$$

$$R_{0,m} \sim \mathcal{N}^+(2.4, \kappa)$$

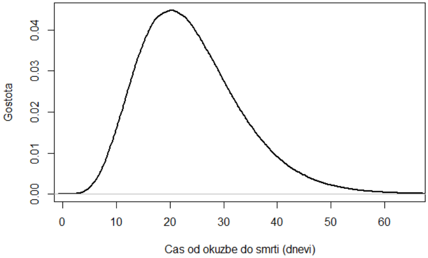
$$\alpha_l \sim \text{gamma}(0.5, 1), \quad l = 1, \ldots, 6$$

$$\kappa \sim \mathcal{N}^+(0, 0.5)$$

$$D_{t,m} \sim \text{NegBin}\left(d_{t,m}, d_{t,m} + \frac{d_{t,m}^2}{\phi}\right)$$

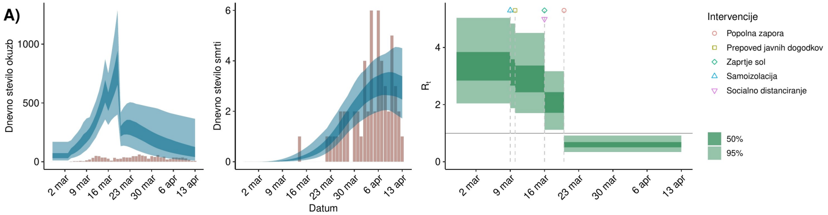
$$d_{t,m} = \tau_m \sum_{k=1}^{t-1} c_{k,m} \pi_{t-k}$$

$$\phi \sim \mathcal{N}^+(0,5)$$



Do we need non-pharmaceutical interventions?

Manevski et al. (ZV, 2020). Data on deceased subjects until 13. of April 2020.



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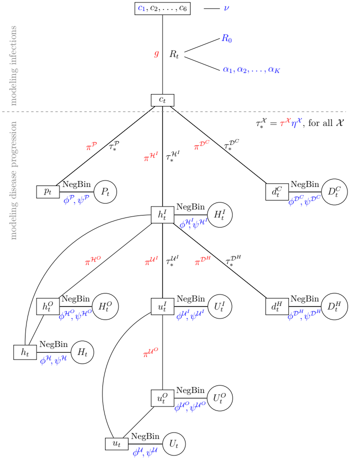

https://oblak8.mf.uni-lj.si/covid19/

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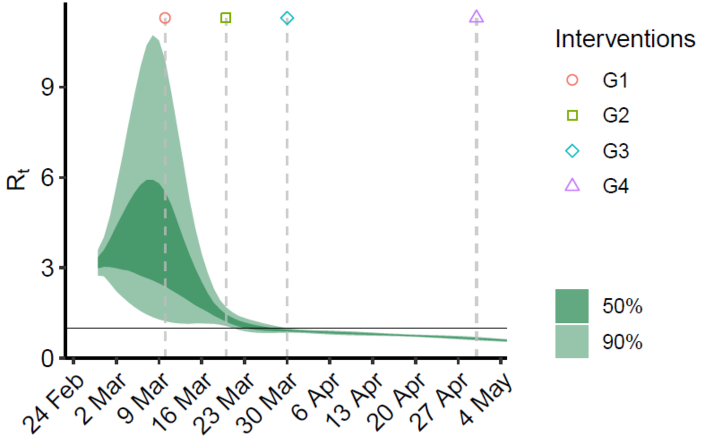

Was the first Covid-19 wave in March 2020 really small in Slovenia?

$$\text{IFR} = \frac{\text{deceased}}{\text{infected}} = \frac{\sum D_t}{\sum c_t} \leq \text{CFR} = \frac{\text{deceased}}{\text{confirmed infections}} = \frac{\sum D_t}{\sum P_t}$$

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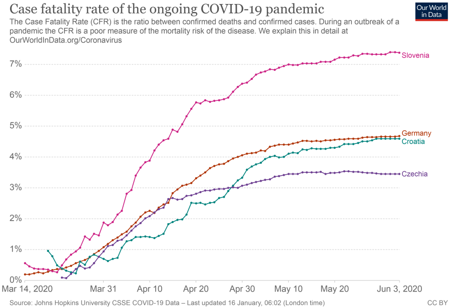

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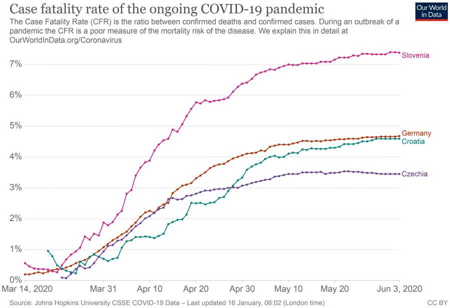

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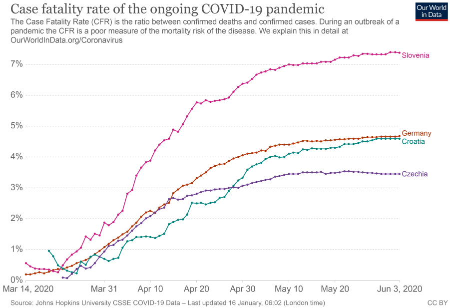

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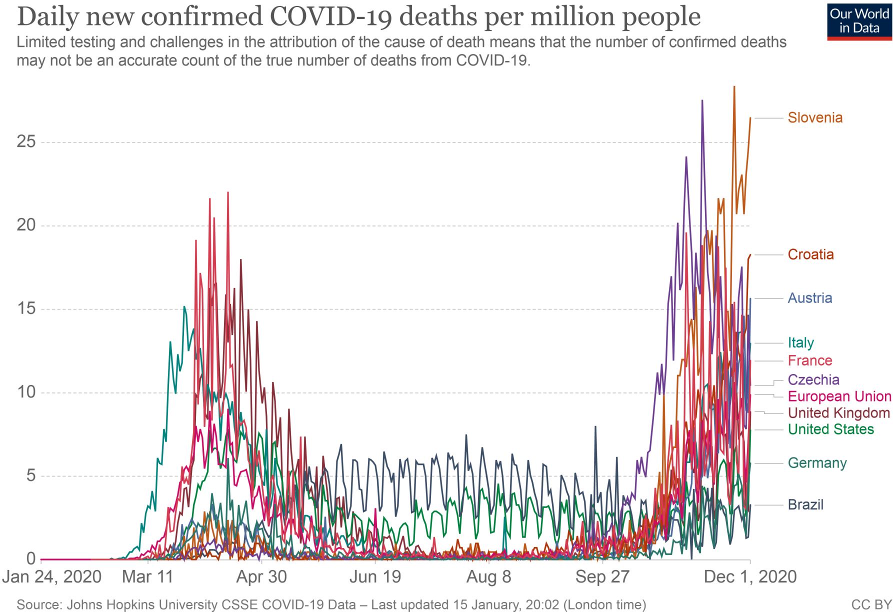
Ioannidis (2021): France, Germany, Switzerland <0.5 %, Spain ≈ 1 %

Was there a catastrophe?



Was there a catastrophe?

Total number of deaths 28. 2. 2020 - 30. 6. 2020: 111

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Tabela: Number of confirmed infections (P) and deceased (D) on one milion people in a 14-day interval. Source: sledilnik/SURS.

	Feb 28 - Jun 30	Jul 1 - Dec 1	Jul 1 - Oct 25	Oct 26 - Dec 1
P	88	3410	1295	10096
D	6	60	7	227

What could have gone wrong? Source: Sledilnik

First wave (until 30. 6. 2020)

Date	NPI	$\sum P_t$	H_t	U_t	$\sum D_t$
10.3.2020	banned public events	49	0	0	0
20.3.2020	lockdown	368	46	8	0
30.3.2020	restriction on municipalities	802	117	29	1

What could have gone wrong? Source: Sledilnik

First wave (until 30. 6. 2020)

Date	NPI	$\sum P_t$	H_t	U_t	$\sum D_t$
10.3.2020	banned public events	49	0	0	0
20.3.2020	lockdown	368	46	8	0
30.3.2020	restriction on municipalities	802	117	29	1

Second wave (from 1.7.2020 onwards)

Date	NPI	$\sum P_t$	H_t	U_t	$\sum D_t$
9.10.2020	**complete** contact tracing not possible anymore	6641	138	23	54
20.10.2020	regions (*curfew*)	14380	313	55	81
26.10.2020	*complete* lockdown	24002	523	82	140
27.10.2020	restriction on municipalities	26612	560	88	153

Mobility data

Source: Google Mobility Report
Daily changes in mobility for the period 3. 1. 2020 do 6. 2. 2020 for people using Google location data.

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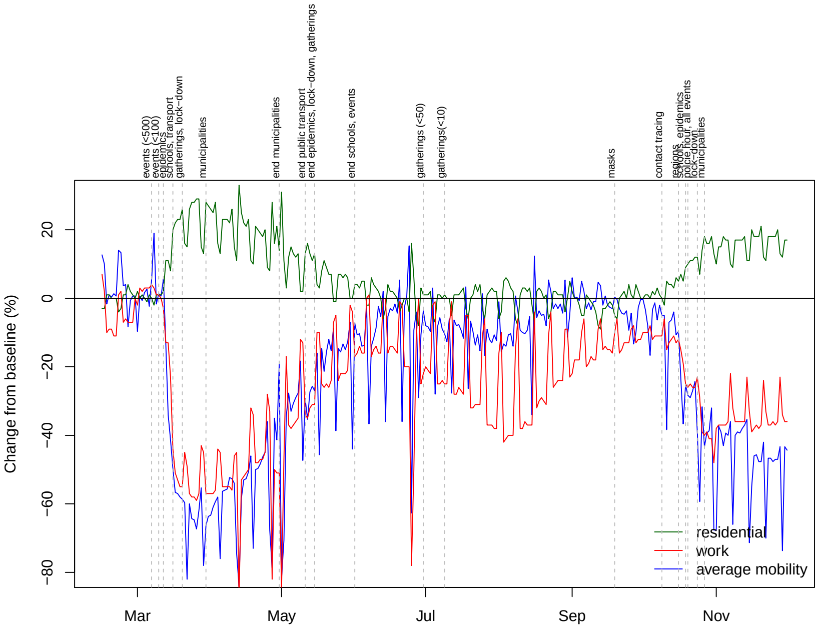
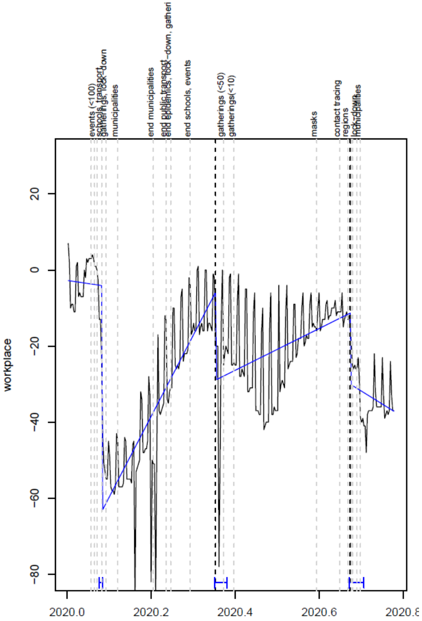
Daily changes in mobility for the period 3. 1. 2020 do 6. 2. 2020 for people using Google location data.
Three mobility dimensions are incorporated:

- *residential* (mobility trend for places of residence)
- *workplace* (mobility trend for places of work)
- *average* mobility (daily average of mobility trends for places like grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies; mobility trends for places like public transport hubs such as bus and train stations; and mobility trends for places like restaurants, cafes, shopping centers, museums, libraries, and movie theaters).

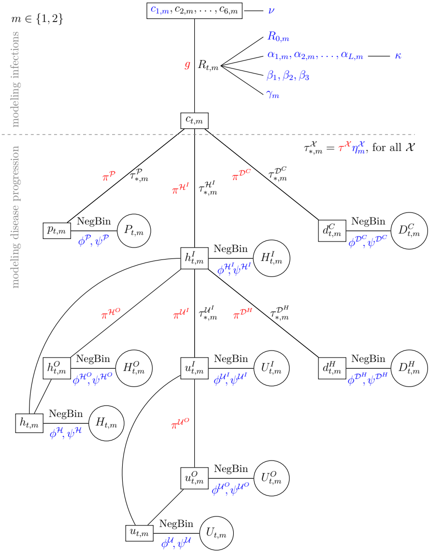
Mobility data



Interventions and mobility data



Model



$m \in \{1,2\}$
modeling infections
modeling disease progression
$c_{1,m}, c_{2,m}, \ldots, c_{6,m}$
ν
$R_{0,m}$
$\alpha_{1,m}, \alpha_{2,m}, \ldots, \alpha_{L,m}$
κ
$\beta_1, \beta_2, \beta_3$
γ_m
g
$R_{t,m}$
$c_{t,m}$
$\tau^{\mathcal{X}}_{*,m} = \tau^{\mathcal{X}} \eta^{\mathcal{X}}_m$, for all $\mathcal{X}$
$\pi^{\mathcal{P}}$ $\tau^{\mathcal{P}}_{*,m}$
$\pi^{\mathcal{H}^I}$ $\tau^{\mathcal{H}^I}_{*,m}$
$\pi^{\mathcal{D}^C}$ $\tau^{\mathcal{D}^C}_{*,m}$
$p_{t,m}$ NegBin $P_{t,m}$ $\phi^{\mathcal{P}}, \psi^{\mathcal{P}}$
$d^C_{t,m}$ NegBin $D^C_{t,m}$ $\phi^{\mathcal{D}^C}, \psi^{\mathcal{D}^C}$
$h^I_{t,m}$ NegBin $H^I_{t,m}$ $\phi^{\mathcal{H}^I}, \psi^{\mathcal{H}^I}$
$\pi^{\mathcal{H}^O}$
$\pi^{\mathcal{U}^I}$ $\tau^{\mathcal{U}^I}_{*,m}$
$\pi^{\mathcal{D}^H}$ $\tau^{\mathcal{D}^H}_{*,m}$
$h^O_{t,m}$ NegBin $H^O_{t,m}$ $\phi^{\mathcal{H}^O}, \psi^{\mathcal{H}^O}$
$u^I_{t,m}$ NegBin $U^I_{t,m}$ $\phi^{\mathcal{U}^I}, \psi^{\mathcal{U}^I}$
$d^H_{t,m}$ NegBin $D^H_{t,m}$ $\phi^{\mathcal{D}^H}, \psi^{\mathcal{D}^H}$
$h_{t,m}$ NegBin $H_{t,m}$ $\phi^{\mathcal{H}}, \psi^{\mathcal{H}}$
$\pi^{\mathcal{U}^O}$
$u^O_{t,m}$ NegBin $U^O_{t,m}$ $\phi^{\mathcal{U}^O}, \psi^{\mathcal{U}^O}$
$u_{t,m}$ NegBin $U_{t,m}$ $\phi^{\mathcal{U}}, \psi^{\mathcal{U}}$

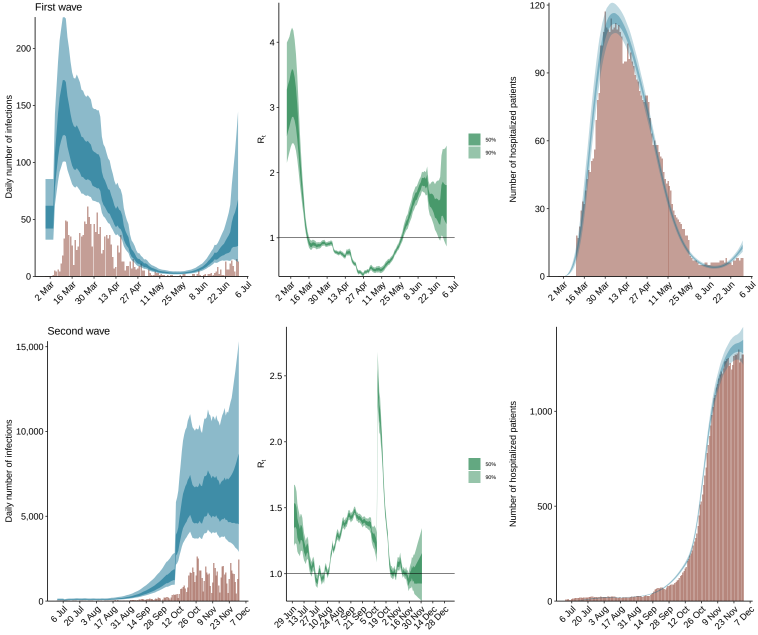
Model

$$R_{t,m} = R_{0,m}\left[2f\left(-\sum_{k=1}^{3}\beta_k z_{k,t,m}\right)\exp\left(\sum_{l=1}^{L}\alpha_{l,m}s_{l,t,m}\right)\exp\left(\gamma_m I_{t,m}\right)\right]$$

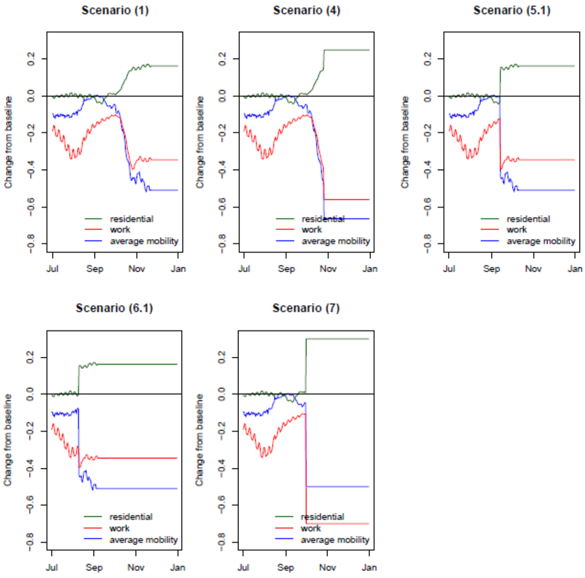
$$R_{0,m} \sim \mathcal{N}^+(3.28, 0.25)$$

$$\begin{aligned}\beta_k &\sim \mathcal{N}(0, 0.5), \quad k = 1, 2, 3,\\ \gamma_m &\sim \mathcal{N}(0, 0.5), \quad m = 1, 2.\end{aligned}$$

$$\begin{aligned}\alpha_{l,m} &\sim \mathcal{N}(0, \kappa), \quad l = 1, \ldots, L,\ m = 1, 2,\\ \kappa &\sim \mathcal{N}^+(0, 0.5).\end{aligned}$$

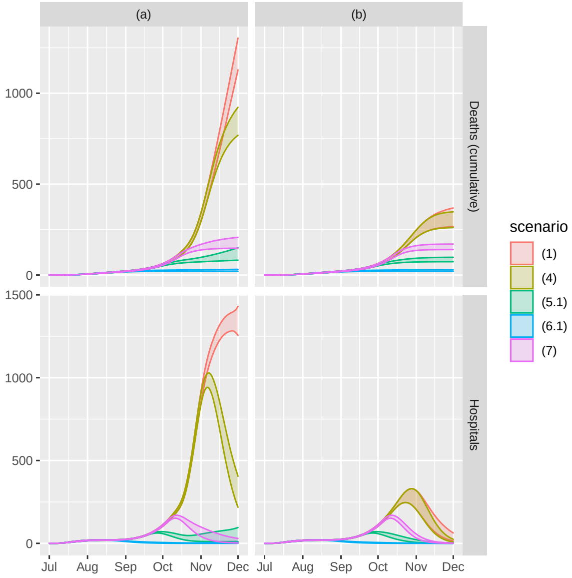

First wave
Daily number of infections
200
150
100
50
0
2 Mar
16 Mar
30 Mar
13 Apr
27 Apr
11 May
25 May
8 Jun
22 Jun
6 Jul
R_t
4
3
2
1
50%
90%
Number of hospitalized patients
120
90
60
30
Second wave
15,000
10,000
5,000
6 Jul
20 Jul
3 Aug
17 Aug
31 Aug
14 Sep
28 Sep
12 Oct
26 Oct
9 Nov
23 Nov
7 Dec
2.5
2.0
1.5
1.0
29 Jun
13 Jul
27 Jul
10 Aug
24 Aug
7 Sep
21 Sep
5 Oct
19 Oct
2 Nov
16 Nov
30 Nov
14 Dec
28 Dec
1,000
500

Scenarios



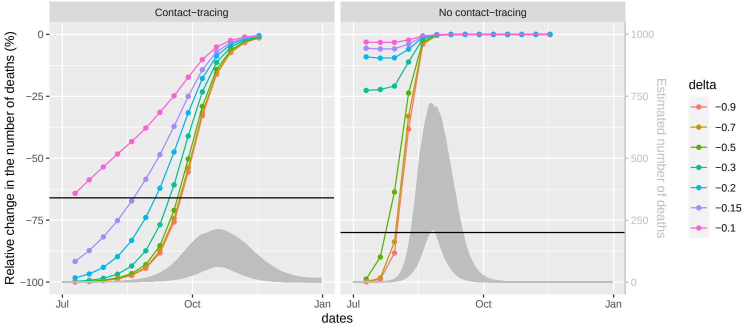
Scenario (1)
Scenario (4)
Scenario (5.1)
Scenario (6.1)
Scenario (7)
Change from baseline
0.2
0.0
-0.2
-0.4
-0.6
-0.8
Jul
Sep
Nov
Jan
residential
work
average mobility

Results



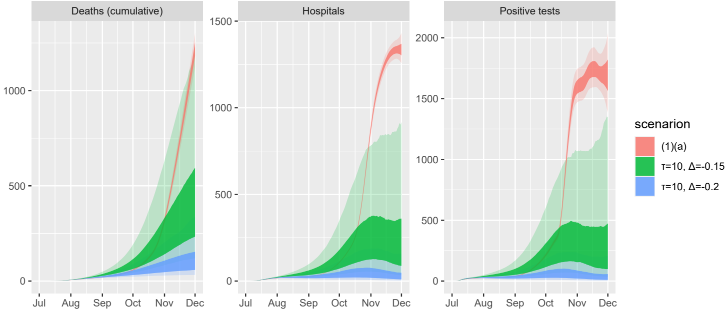
(a)
(b)
Deaths (cumulative)
Hospitals
1000
500
0
1500
1000
500
0
Jul
Aug
Sep
Oct
Nov
Dec
Jul
Aug
Sep
Oct
Nov
Dec
scenario
(1)
(4)
(5.1)
(6.1)
(7)

Results



Contact−tracing
No contact−tracing
Relative change in the number of deaths (%)
0
−25
−50
−75
−100
Estimated number of deaths
1000
750
500
250
0
Jul
Oct
Jan
Jul
Oct
Jan
dates
delta
−0.9
−0.7
−0.5
−0.3
−0.2
−0.15
−0.1

Results



Deaths (cumulative)
Hospitals
Positive tests
1000
500
0
1500
1000
500
0
2000
1500
1000
500
0
Jul
Aug
Sep
Oct
Nov
Dec
scenarion
(1)(a)
τ=10, Δ=-0.15
τ=10, Δ=-0.2

Limitations

Assumptions (the time distributions, IFRs,...).

The data quality and availability.

High correlation between the mobility dimensions.

NPI and other factors might influence the spread of the virus (masks, schools, etc.).

Observational study using aggregated data.

One country.

Contact tracing.