Expected impact of COVID-19 outbreak in a major metropolitan area in Brazil

The case of Brasília – Federal District (DF)

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COVID 19 - MODELING INFECTION DYNAMICS

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The model

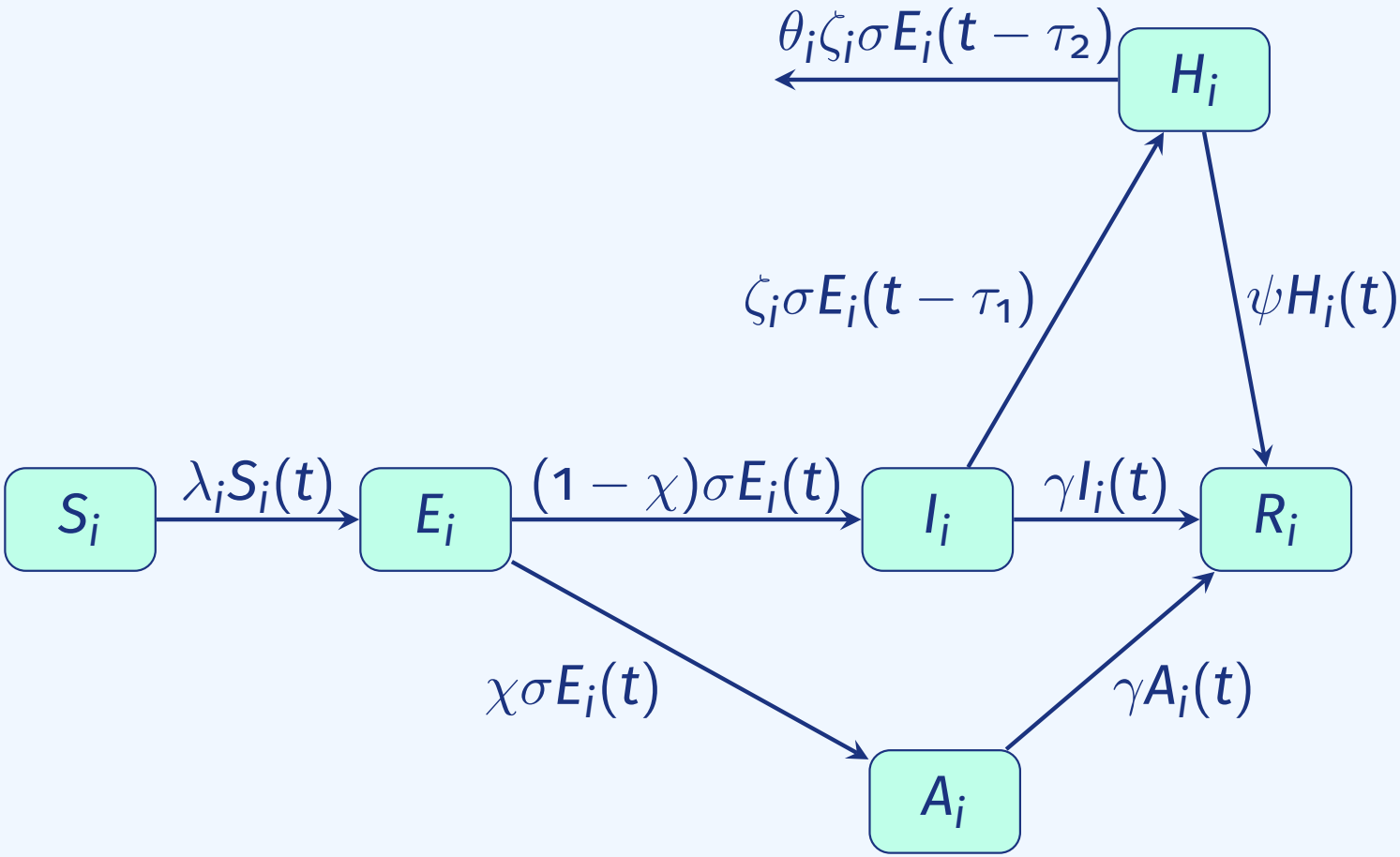
Model variables

Variable	Description
S_i	Susceptible individual in age group i.
E_i	Exposed individuals (non-infectious).
I_i	Symptomatic infected individuals.
A_i	Asymptomatic infected individuals.
H_i	Hospitalized individuals.
R_i	Recovered individuals.

Model Parameters

ψ	Recovery rate from hospital	$1/17.5$ days^{-1}
P_{sc}	Prop. of severe and critical cases	18%
μ_{COV}	Fatality for detected cases	$1\%(0.4\%, 2.9\%)$
θ_i	Fatality for hospit. individuals	μ_{COV}/P_{sc} overall
ζ_i	Hospitalization probability	5.8% symp. overall
σ^{-1}	Inverse of the incubation time	$5.0\,(4.2, 6.0)$ days^{-1}
γ^{-1}	Inverse of infectiousness time	$1.61\,(0.35, 3.23)$ days^{-1}
ζ_i	Hospitalization probability	0.8% overall
R_0	Basic reproduction number	$3.0\,(2.5, 3.5)$
τ_1	time from 1st symptom to hospital.	$3.3\,(2.7, 4.0)$
τ_2	time from 1st symptom to death	$15.0\,(12.8, 17.5)$
χ	Proportion of non detected cases	$86.2\%(81.6\%, 89.8\%)$
ξ	Asymp. infectiousness w.r.t. symp.	$55\%(46\%, 65\%)$

Model Diagram



Model Equations

$$
\begin{aligned}
\frac{dS_i}{dt} &= -\lambda_i S_i \\
\frac{dE_i}{dt} &= \lambda S_i - \sigma E_i, \\
\frac{dI_i}{dt} &= (1-\chi)\sigma E_i - \gamma I_i - \zeta_i \sigma E_1(t-\tau_1), \\
\frac{dA_i}{dt} &= \chi\sigma E_i - \gamma A_i, \\
\frac{dH_i}{dt} &= -\psi H_i + \zeta_i \sigma E_i(t-\tau_1) - \theta\zeta_i\lambda_i E_i(t-\tau_2), \\
\frac{dR_i}{dt} &= \gamma I_i + \gamma A_i + \psi H_i, \qquad (1)
\end{aligned}
$$

Force of infection:

$$\lambda_i = \sum_{j=1}^{M} \beta_{i,j} \frac{I_j}{n_i}.$$

Basic reproduction number and effective reproduction number:

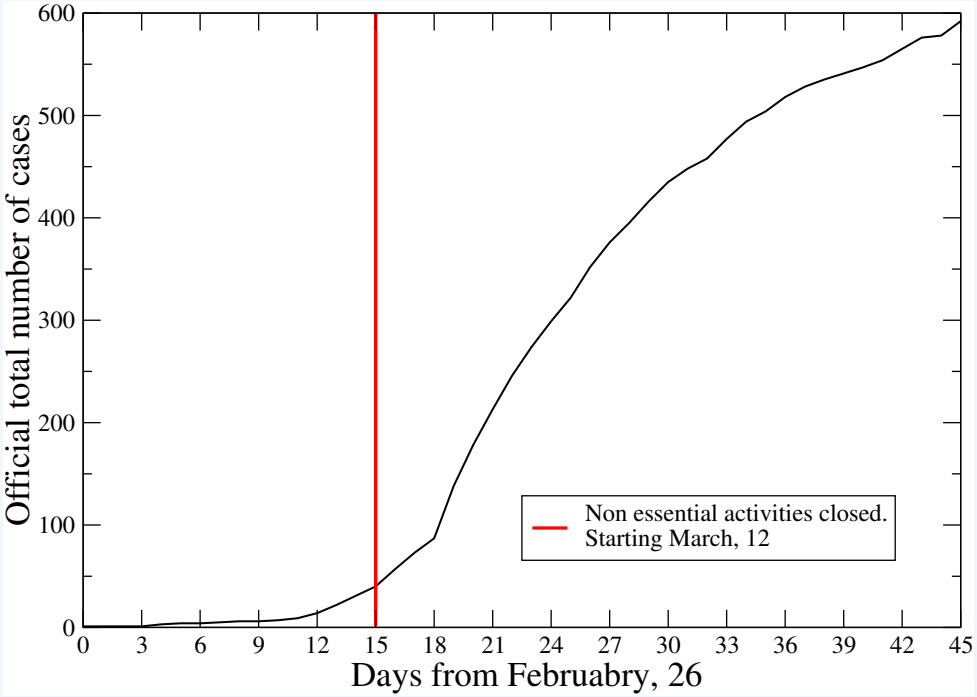
$$R_0 = \sum_{j=1}^{M} n_j R_0^{(j)}, \qquad R_0^{(j)} = \sum_{i=1}^{M} \beta_{ij}/\gamma.$$

$$R_e = \sum_{j=1}^{M} S_j R_0^{(j)}, \qquad R_e^{(j)} = \sum_{i=1}^{M} \beta_{ij}/\gamma.$$

$$\beta_{ij} = \rho_i C_{ij}.$$

$C_{ij} \rightarrow$ Average number of contacts of an individual of age group j with any individual of group i.
$\rho_i \rightarrow$ Probability of a susceptible individual of group i being infected by any infected individual during a contact.

Official number of cases for Brasília – 2/26 to 3/13

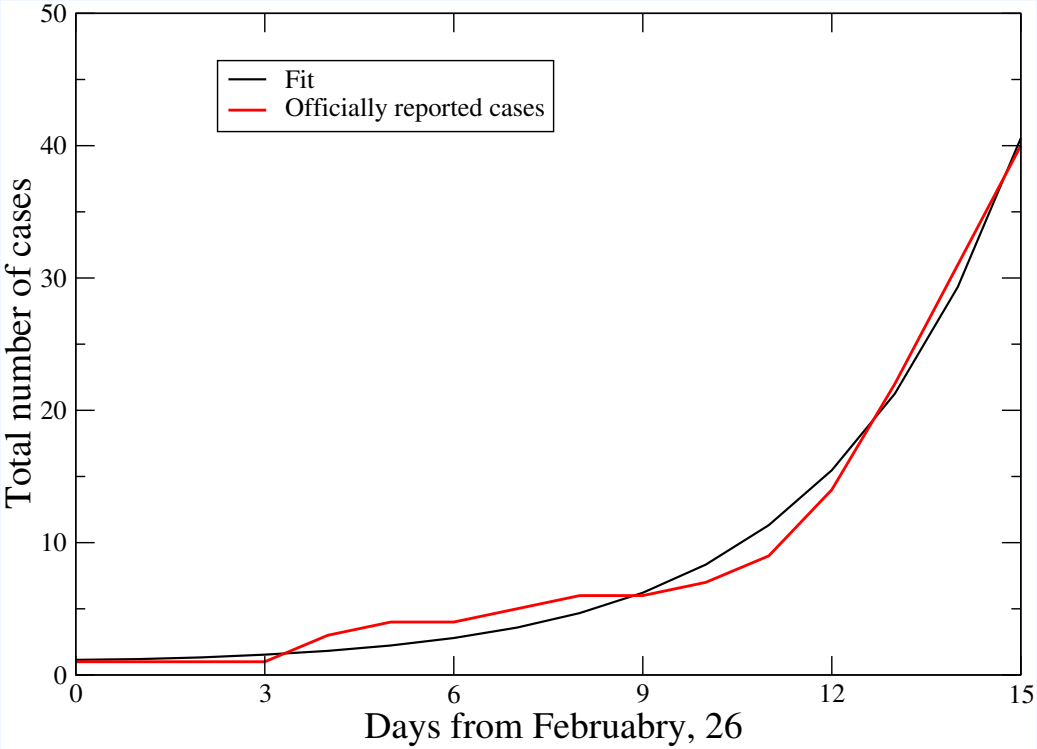


- Only severe and critical cases have been tested ($\approx$ 18%).
- Despite the high number of non reported symptomatic cases (estimated $\approx$ 10-fold), we expect that up to March, 12 they are a constant proportion of the real numbers.
- Estimated total population in the Federal District: 3 Million.

The Basic Reproduction Number

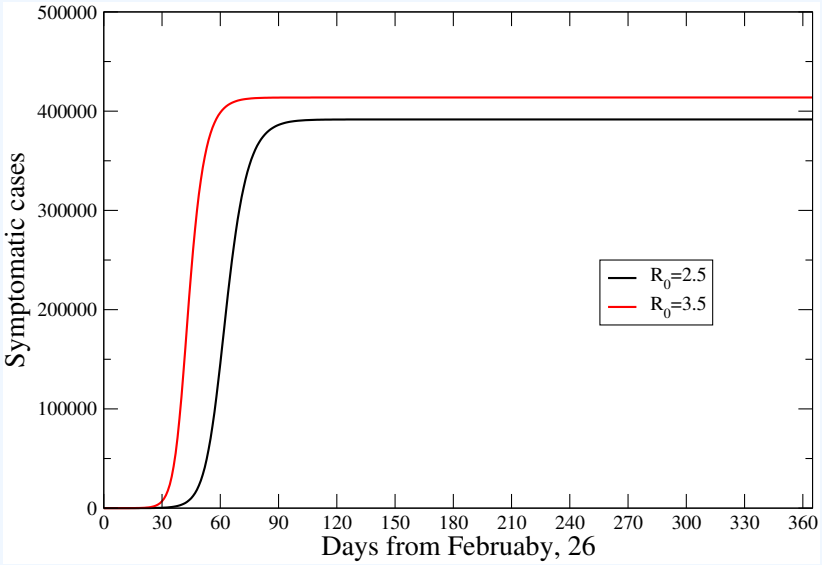
R_0 FROM MODEL FITTING

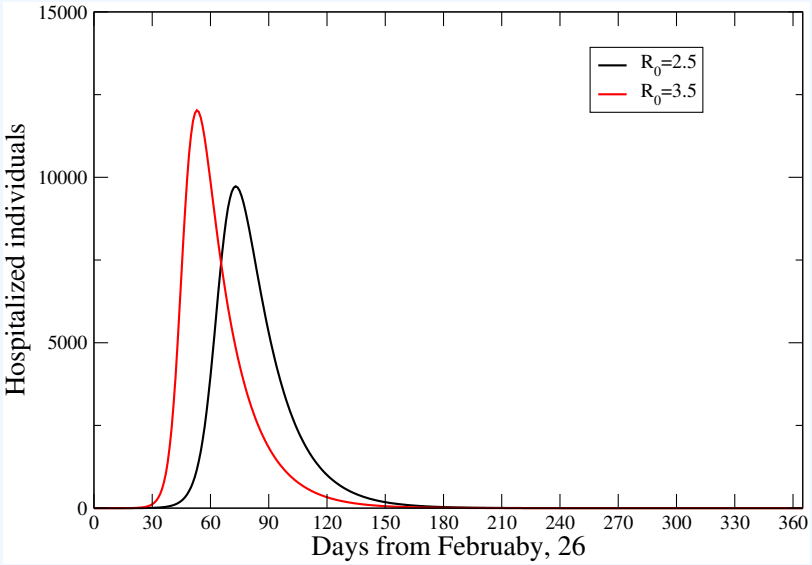
- As the total number of cases is small, we used the model without age-stratification to fit R_0.

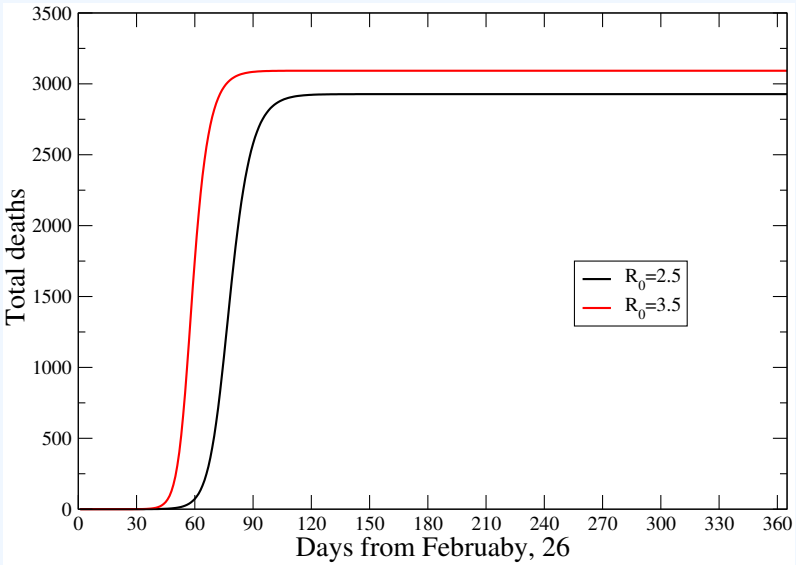


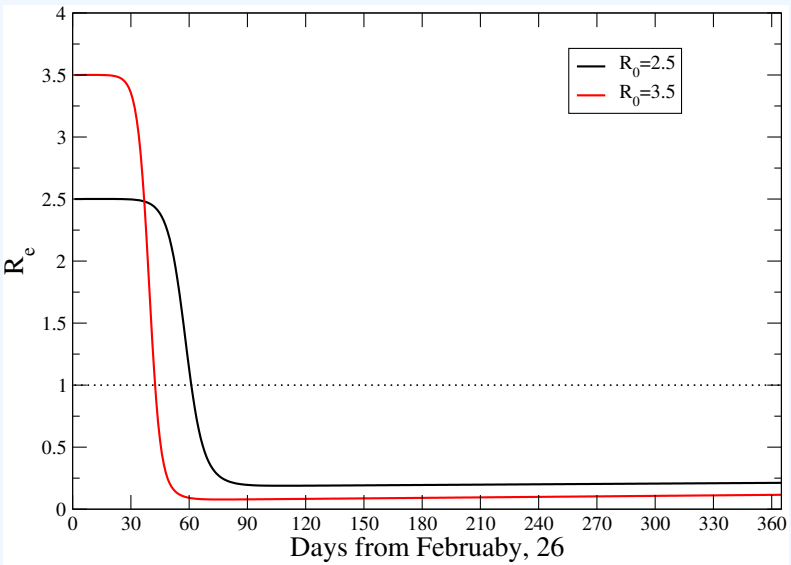
- From 2/26 to 3/12 $\rightarrow$ $R_0 = 3.58$.
- From 2/26 to 3/10 $\rightarrow$ $R_0 = 3.45$.
- From 2/26 to 3/14 $\rightarrow$ $R_0 = 3.19$.

Trend with no Isolation


Symptomatic cases
Days from Februaby, 26
R_0=2.5
R_0=3.5


Hospitalized individuals
Days from Februaby, 26
R_0=2.5
R_0=3.5


Total deaths
Days from Februaby, 26
R_0=2.5
R_0=3.5


R_e
Days from Februaby, 26
R_0=2.5
R_0=3.5

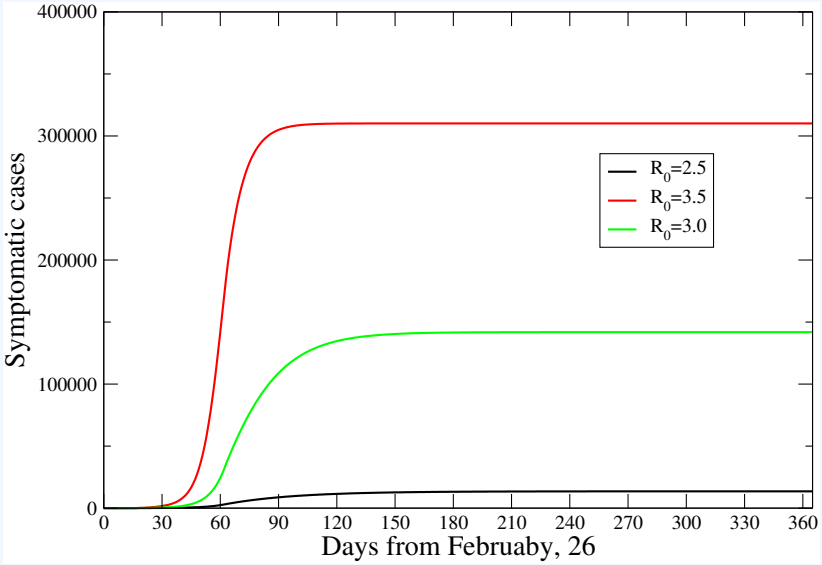
Hospital facilities in Brasília

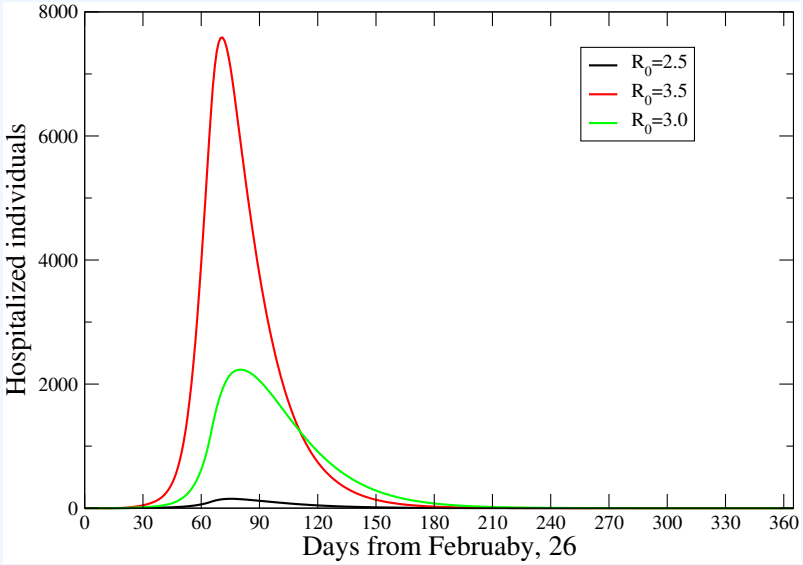
- Total number of ICUs: 1700.
- Total number of infirmary beds (Non-ICUs): 6700;
- Expected ICUs required: 2400–3000.
- Expected non-ICU beds: 7300–9000.
- Most ICU beds are (80%) on the private sector.
- ICU occupancy is usually never below 60%.

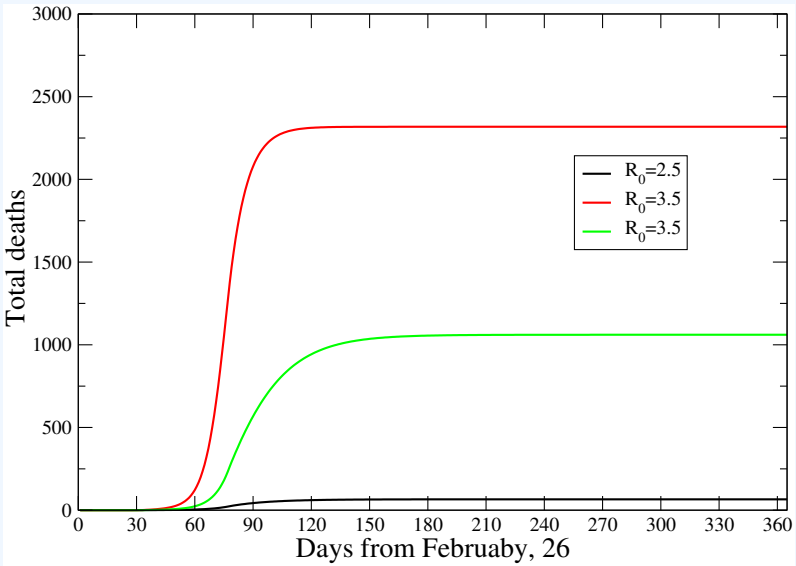
Trends with Isolation

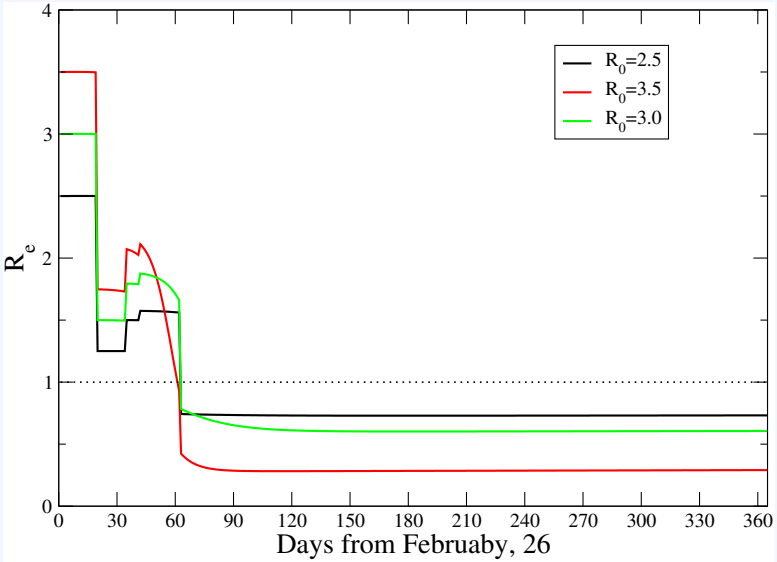
Current isolation becoming more strict later

- February, 26 to March, 11 $\rightarrow$ no isolation.
- March, 12 to March, 30 $\rightarrow$ 40% reduction in contacts.
- March, 31 to April, 4 $\rightarrow$ 37% reduction in contacts.
- April, 5 to April, 27 $\rightarrow$ 70% reduction in contacts.
- April, 28 to February, 25 $\rightarrow$ 30% reduction in contacts.

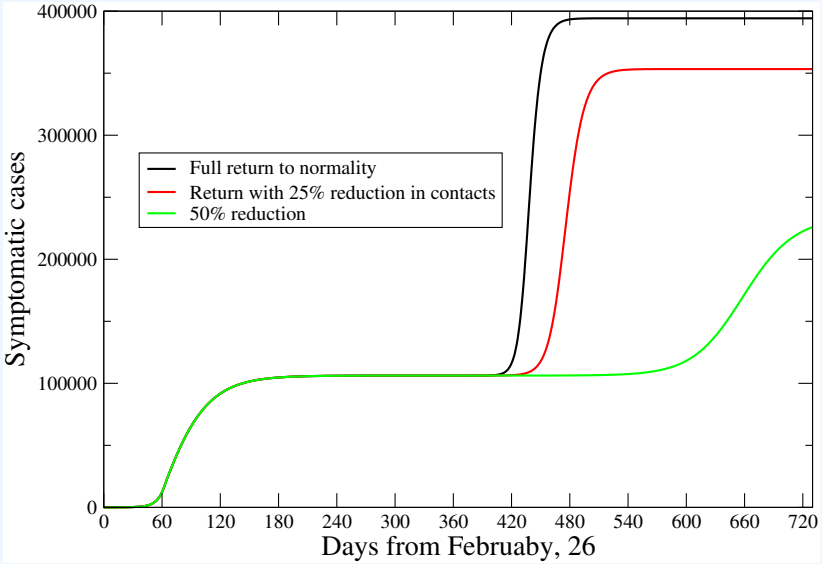

Symptomatic cases
Days from Februaby, 26
R0=2.5
R0=3.5
R0=3.0

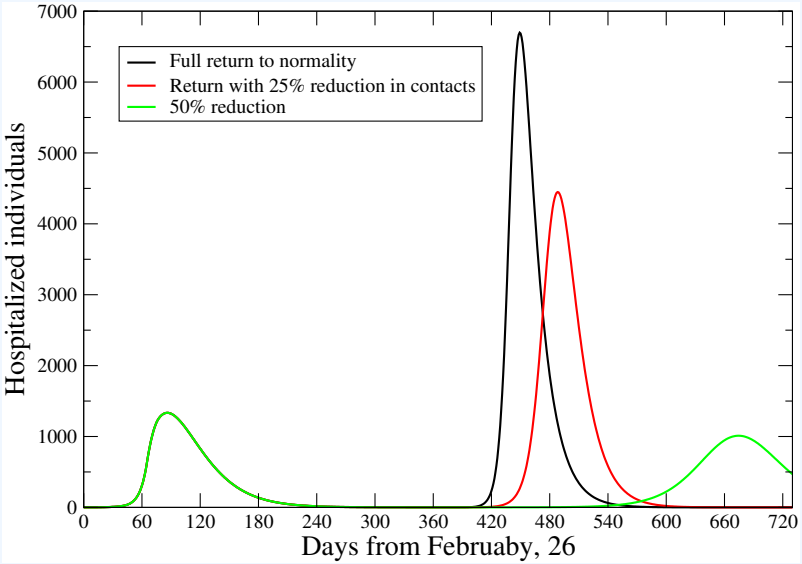

Hospitalized individuals
Days from Februaby, 26
R0=2.5
R0=3.5
R0=3.0

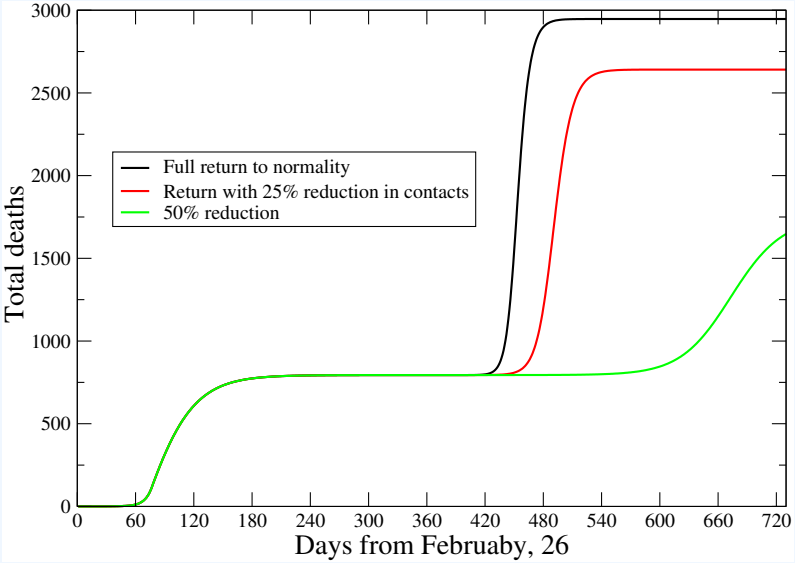

Total deaths
Days from Februaby, 26
R0=2.5
R0=3.5
R0=3.5

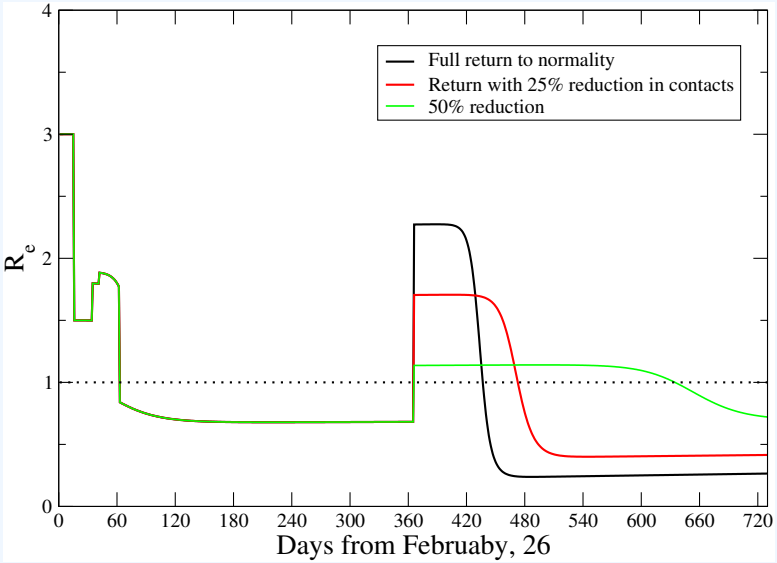

Re
Days from Februaby, 26
R0=2.5
R0=3.5
R0=3.0

End of isolation after one year



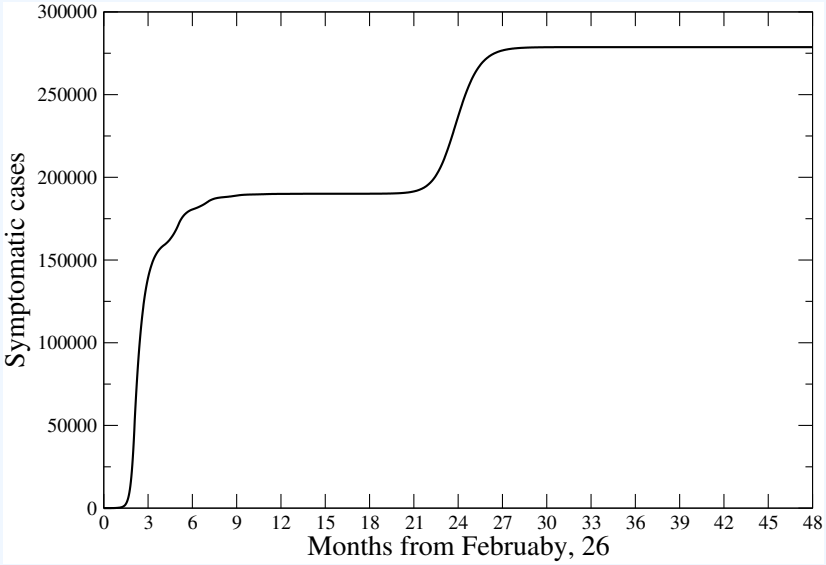


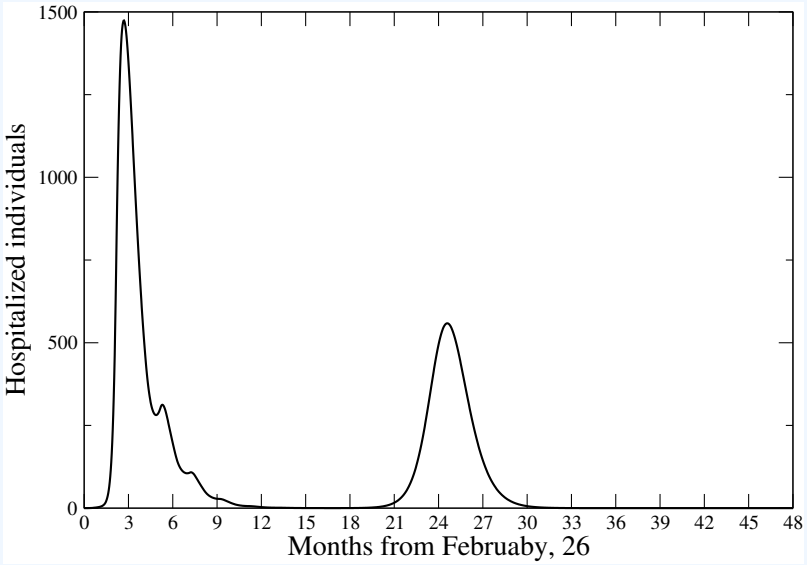


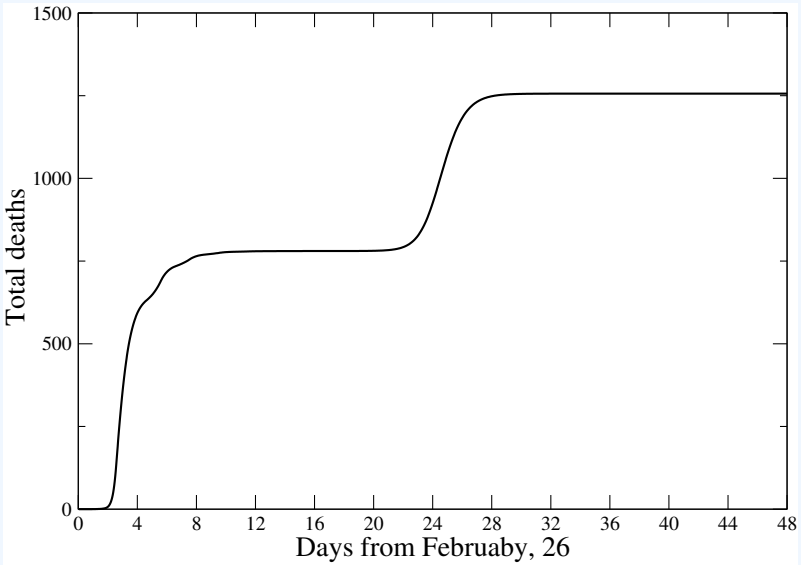


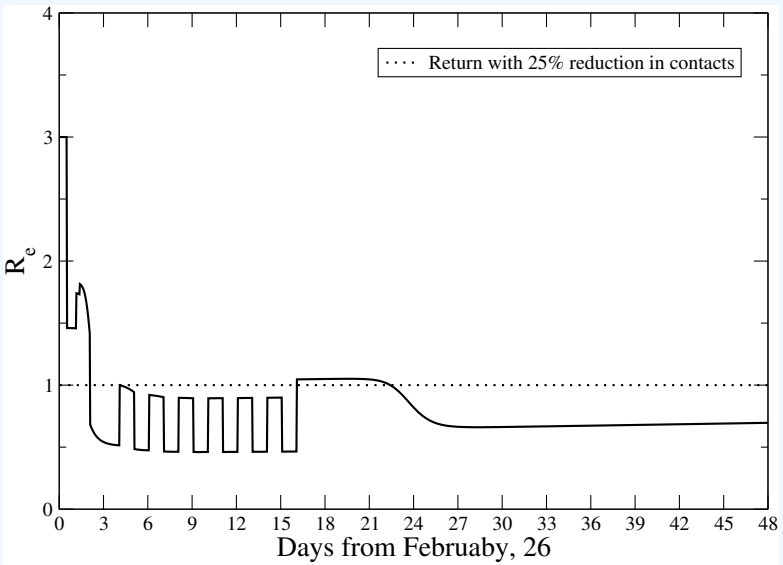
Alternate isolation–partial normality

- Alternate isolation periods with a partial return of social contacts.
- Strict isolation of elders: 70 years of age and more.
- From April, 27 alternate 1 month with isolation (75% reduction of contacts) to a mild return of social contacts (30% reduction) for the people younger than 70 years old, for approximately 16 total time.


Symptomatic cases
Months from Februaby, 26


Hospitalized individuals
Months from Februaby, 26


Total deaths
Days from Februaby, 26


Return with 25% reduction in contacts
R_e
Days from Februaby, 26

Concluding Remarks and Perspectives

- Up to the current knowledge on SARS-CoV-2, the control of the Pandemics is going to take a lot of time and effort.
- Isolation reduces the death toll by avoiding to overwhelm hospital facilities.
- The economic impact is certainly much higher than usually announced.
- Differente models for the dynamics of COVID-19 can help shed some light on different options for the long term control of the disease.
- A possible strategy to reduce the long-term economic impact: alternate isolation and relative return to normality (with reduction of contacts), with special attention to the elders.

- No real return to normality is possible, unless with an efficient vaccine and/or a effective pharmaceutical therapy.
- The result of the partial end of isolation in some countries may lead to important insights for other countries.
- With more data it is possible to obtain the transmission matrix $\beta_{i,j}$ using an estimation of the contact matrix (ongoing for the Federal District) and fitting the probability of transmission for each contact.
- The number of deaths is a proxy for the number of symptomatic cases, and can be used to fit the model.

Thank You for Your attention!