An epidemic model for SARS-CoV-2 with self-adaptive containment measures

By Sabina Marchetti, Alessandro Borin, Francesco Paolo Conteduca, Giuseppe Ilardi, Giorgio Guzzetta, Piero Poletti, Patrizio Pezzotti, Antonino Bella, Paola Stefanelli, Flavia Riccardo, Stefano Merler, Andrea Brandolini, Silvio Brusaferro

System & software requirements

Cpu: 20 physical cores Intel(R) Xeon(R) CPU E5-2630 v4 @ 2.20GHz

Ram: 256 GB

O.S.: Red Hat Enterprise Linux Server release 7.9 (Maipo)

GCC: gcc (GCC) 4.8.5 20150623 (Red Hat 4.8.5-44)

GSL: version 1.16

R version: 4.0.5 (2021)

zoo R package: version 1.8.9

EpiEstim R package: version 2.2.4

Demo:

```
bash Run_scenario.sh N_Weeks Framework Policy_Mechanism
```

Argument	Type	Description	Possible values
N_weeks	int	Number of weeks for the simulation	[0,inf)
Framework	int	Type of vaccines rollout used in simulation (1: actual, 2: optimistic, 3: pessimistic)	{1,2,3}
Policy_Mechanism	int	Policy mechanism to simulate (1: Occupancy rates, 2: Incidence, 3: Rt-New positives, 4: Rt-Hospital admissions)	{1,2,3,4}

E.g. Baseline framework with Rt (Hospital Admissions) policy mechanism over 3 weeks:

```
bash Run_scenario.sh 3 1 4
```

Input Description

R = 21; n. regions: (i.e., 19 regions and two autonomous provinces according to the NUTS 2 classification for Italy)

A = 5; n. age classes (i.e., 0-12, 13-18, 19-64, 65-79,80+)

P = 4; n. restriction tiers (i.e., white, yellow, orange, red)

MODEL INITIALIZATION		
Parameter name	**Description**	**Dimensions (rows x columns)**
popreg	Regional population	Rx1
inf	Infectious & non-vaccinated individuals	RxA
Prev_variant2	Regional prevalence of variant 2	Rx1
vcomp*k*; k=1,2	Vaccinated & susceptible individuals	RxA
propFirstDose	Share of individuals with one dose only	Ax1
BTIinf	Infectious & vaccinated infections	RxA
Hpeople	Hospitalized individuals in MA	
ICUpeople	Hospitalized individuals in ICU	
propBTIage	Age-specific share of breakthrough infections among hospitalized individuals	Ax1
R	Recovered individuals	RxA
RemB	Recovered & vaccinated individuals	RxA
CONSTANT PARAMETRS		
proppop	Population shares by age and region	RxA
C	Contact matrix by age classes	AxA
regeff	Regional tier effects	Rx1
mobil	Tier-specific mobility levels (pre-covid regime equals 1)	Px1
beta_wild	Baseline transmissibility parameter (wild-type)	1x1
impr_1	Variant 1 improvement in transmissibility	1x1
impr_2	Variant 2 improvement in transmissibility	1x1
gamma	Baseline recovery rate	1x1
suscAge	Age- and variant-specific susceptibility to infection	Ax2
sev	Age-specific risk to develop the severe disease (for variant 1)	1xA
v2_sev	Improvement of sev for variant 2 (with respect to variant 1)	1x1
h	Age-specific probability of being hospitalized among individuals who developed the severe disease	Ax1
ICU	Age-specific probability of being admitted to ICU among hospitalized individuals	Ax1
ifr	Age-specific infection fatality rate among hospitalized individuals	Ax1
hospTime	1/(Average days in medical area)	1x1
ICUtime	1/(Average days in ICU)	1x1
v1_effV1	Efficacy of one dose of vaccine 1 against variant 1	1x1

v2_effV1	Efficacy of one dose of vaccine 2 against variant 1	1x1
v1_effV2	Efficacy of one dose of vaccine 1 against variant 2	1x1
v2_effV2	Efficacy of one dose of vaccine 2 against variant 2	1x1
contrib	Contribution to transmission of the virus among infectious vaccinated individuals	1x1
filter	Share of hospitalizations among vaccinated individuals who developed the severe disease	1x1
DYNAMIC PARAMETERS		
pol	Current and past regional weekly policies affecting current circulation of the virus (includes additional parameter for mobility improvements due to exogenous events: Football Championship and introduction of digital COVID-19 certificate)	(R+1)x4
School	Policy-prescribed regional reductions of contacts among individuals at school	Rx3
Temp_j, j=1,2	Weekly regional deviations from the median temperature (over current and ensuing two weeks)	Rx3
Efficacy1	Weighted regional- and age-specific vaccine efficacy against variant 1 with complete vaccination	RxA
Efficacy2	Weighted regional- and age-specific vaccine efficacy against variant 2 with complete vaccination	RxA
Cov1	Coverage of vaccine group k (first dose)	AxR
Cov2	Coverage of vaccine group 2 (first dose)	AxR
Cov3	Coverage of the boosting campaign (third dose)	AXR

Output Description:

The model produces an output txt file “OUT” in the path folder

`Outs/Mechanism_i_Framework_j`

where *i* belongs to {1,2,3}, and *j* belongs to {1,2,3,4}

E.g. The output resulting from “bash Run_scenario.sh 3 1 4” will be file:

Outs/Mechanism_1_Framework_4/OUT

The txt file is organized into 26 column variables:

1: *Regione*: Region ID

2: *Giorno*: Date (format: YYYY-MM-DD’)

3: *ClasseEta*: Age class: {0: 0-12, 1: 13-18, 2: 19-64, 3: 65-79, 4: 80+}

4: *PopT*: Total population (by region and age class)

5: *Deceased*: Number of deaths (by region and age class)

6: *Incidenza*: New infections (reported and unreported, by region and age class)

7: *Incid_Variant1*: New infections by variant 1 (reported and unreported, by region and age class)

8: *NewHosp*: New hospital admissions (flow)

Column 9 to 25: Model compartments (state variables)

26: *IncidenzaRilevati*: Reported new infections (by region and age class)