COVID-19 Modelling

Scenario Analysis for the Piedmont Region

2021-02-09 | *SEPI-SEREMI*

Overview

Data

- *Population*
- *Contact*
- *Behaviour*
- *Surveillance*
- *Policy*

Modelling

- *Structure*
- *Initialization*
- *Calibration*

Work in Progress

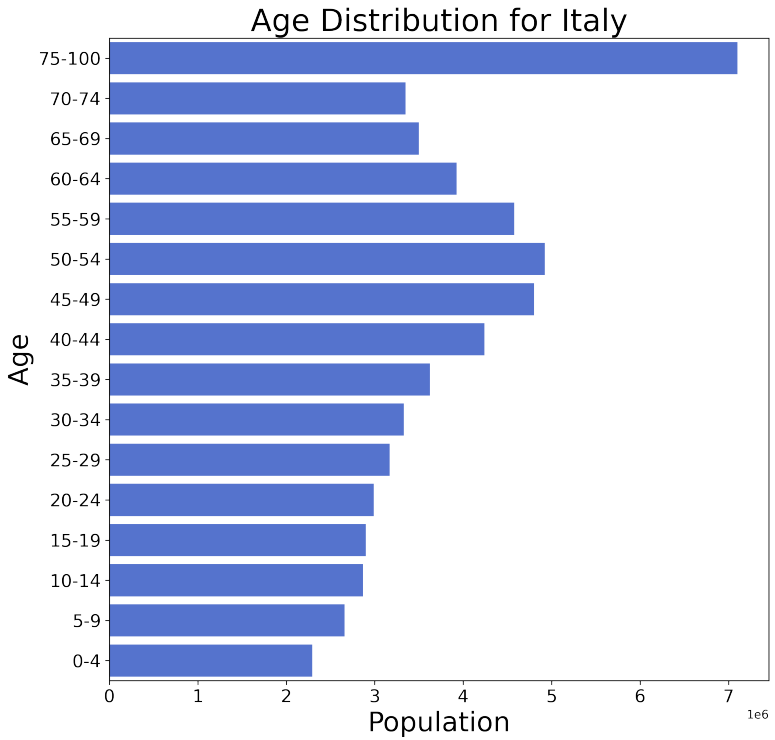
- *Multi-Method R_t Estimation*
- *Identifiability Analysis*
- *Sensitivity Analysis*
- *Validation*

Questions

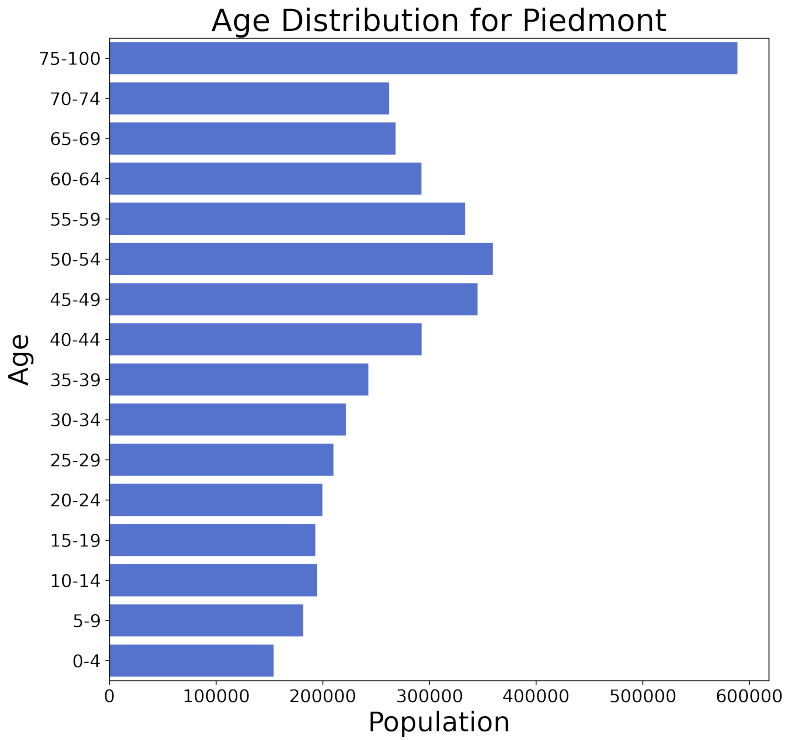
- *Events*
- *Transition Delays*
- *Hospital & ICU Capacity*
- *Diagnostic Capacity*

Population Data

National



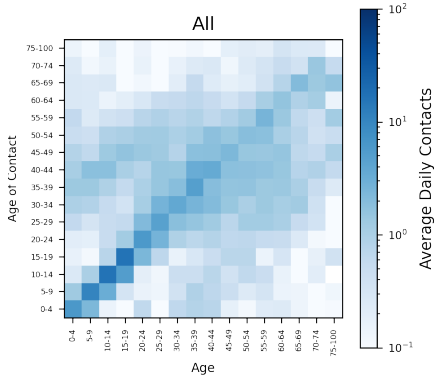
Regional

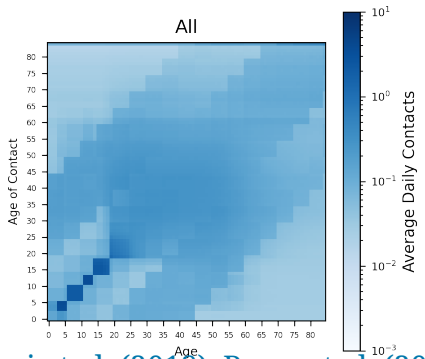


Source: ISTAT (2020)

Contact Data

National





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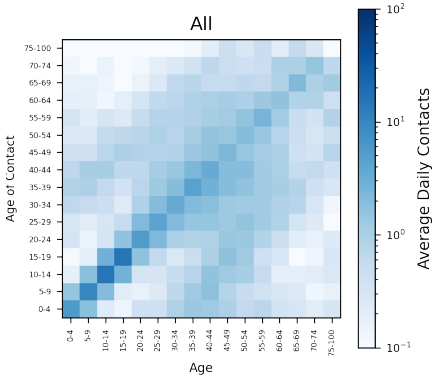
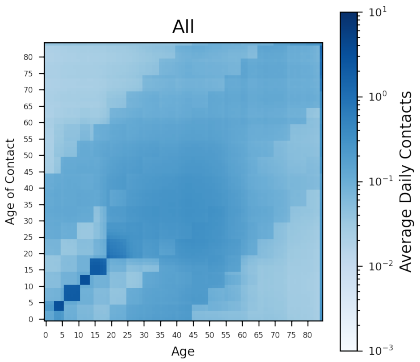
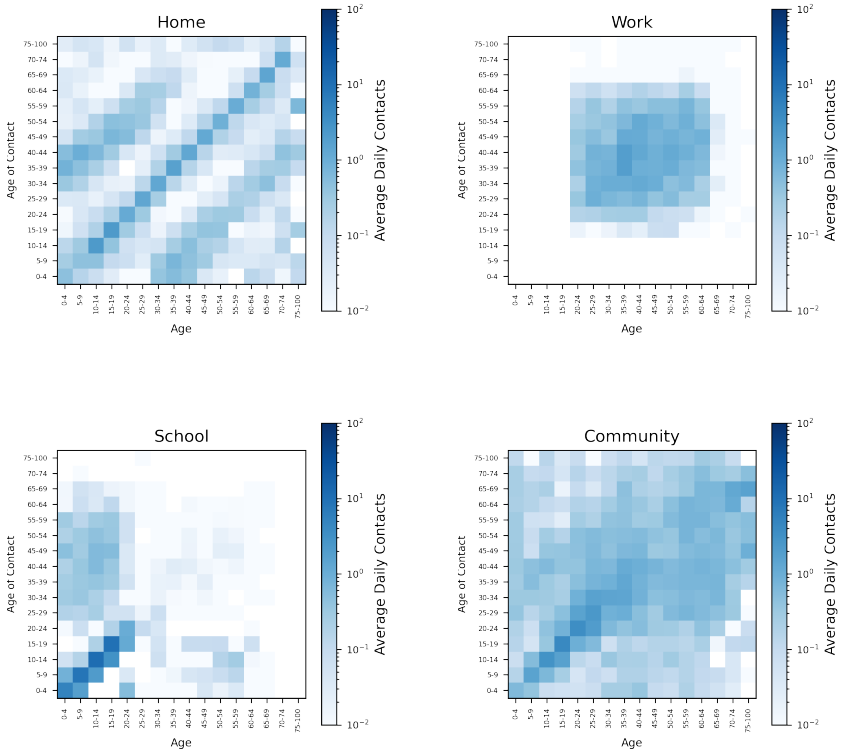




Sources: Arregui et al. (2018), Prem et al. (2020), Mistry et al. (2020)

Contact Data: Medium Resolution

National



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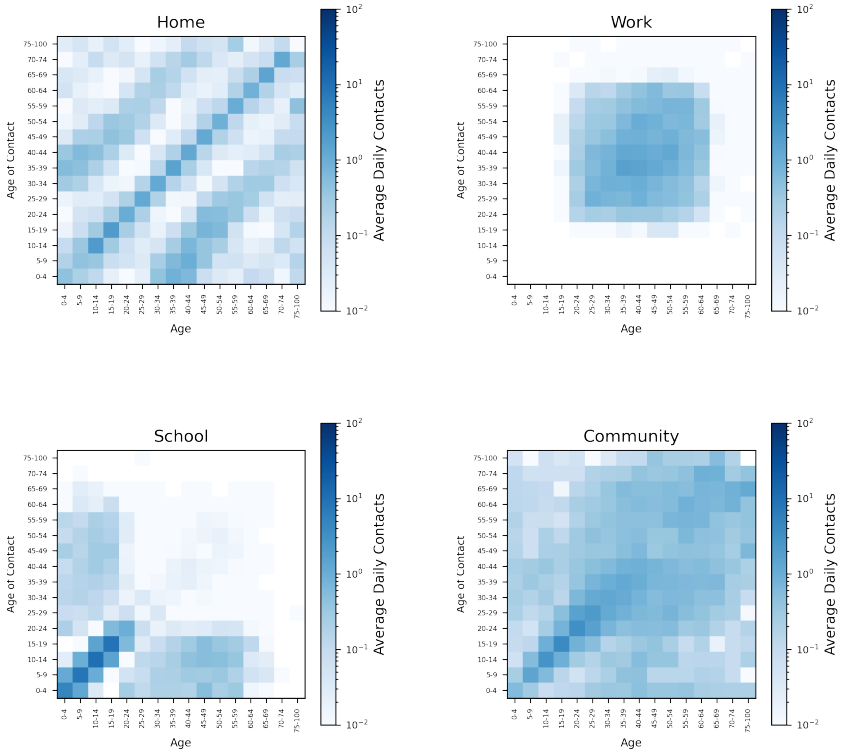

Sources: Arregui et al. (2018), Prem et al. (2020)

Contact Data: High Resolution

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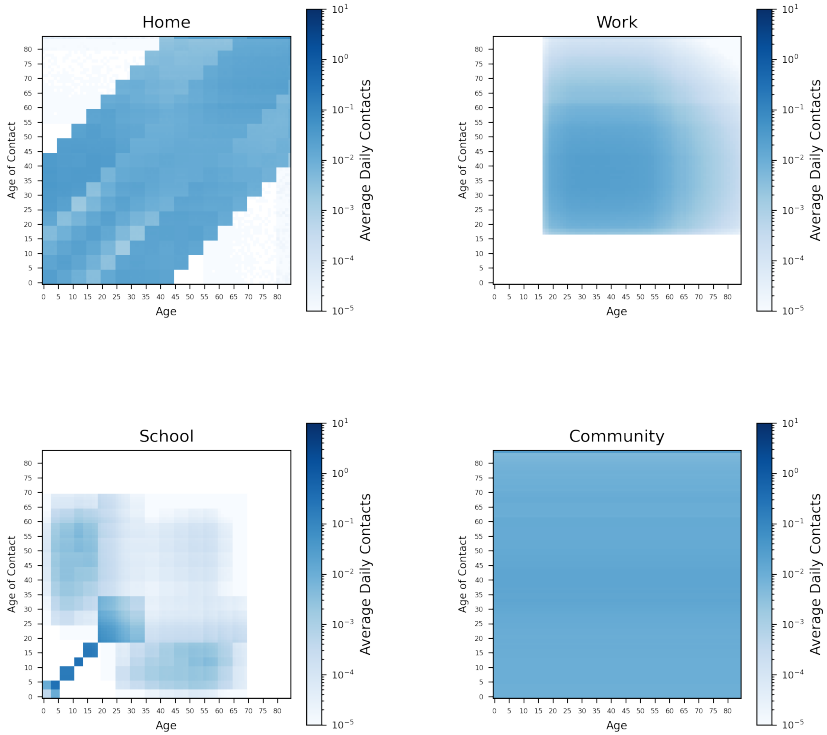

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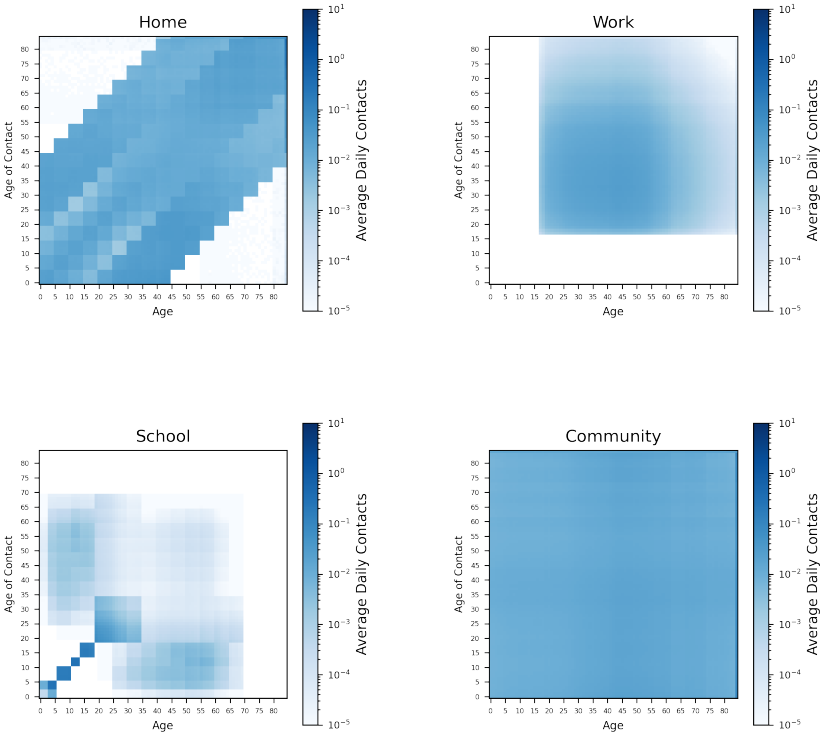
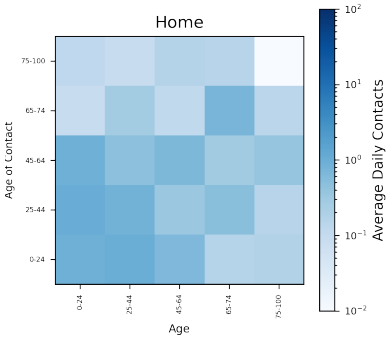
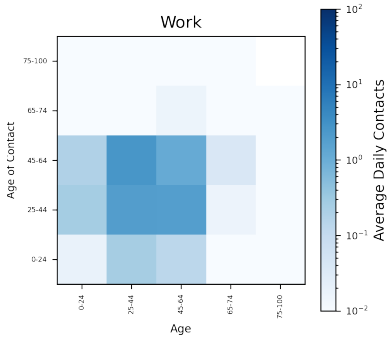


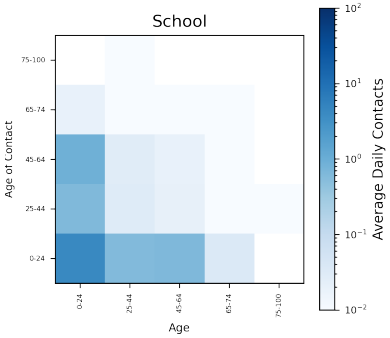
Sources: Arregui et al. (2018), Mistry et al. (2020)

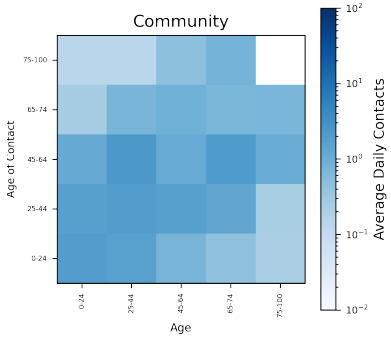
Contact Data: Aggregated

Medium Resolution

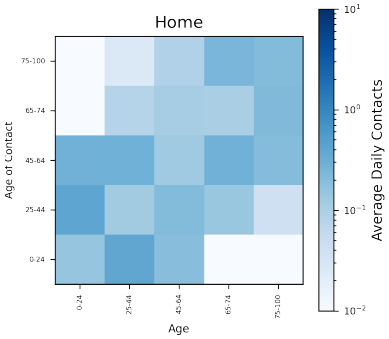


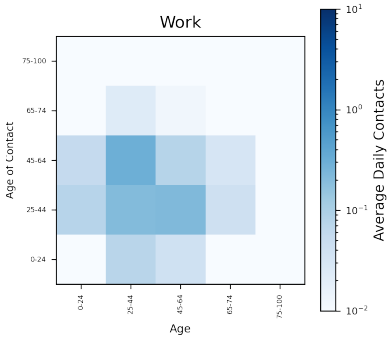


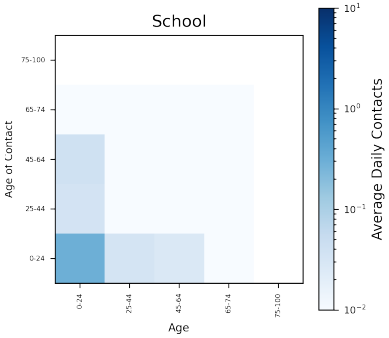


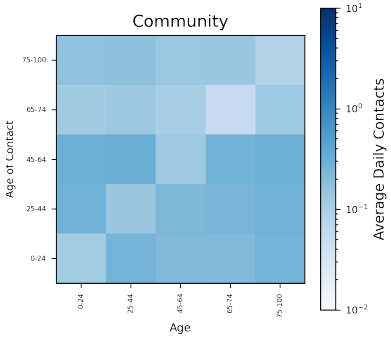


High Resolution



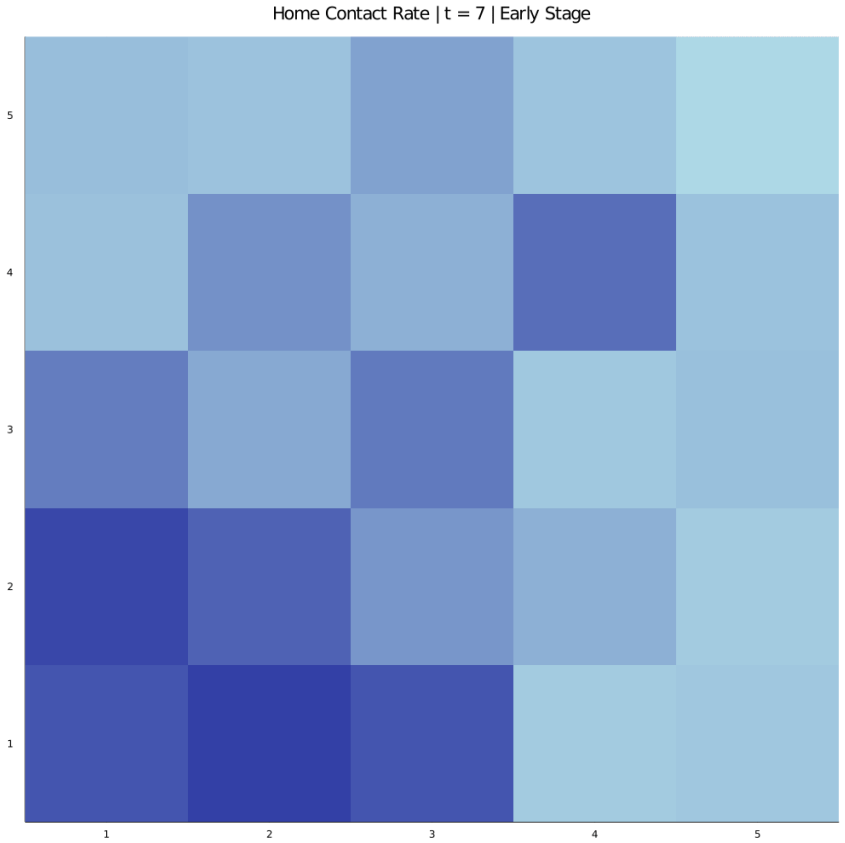


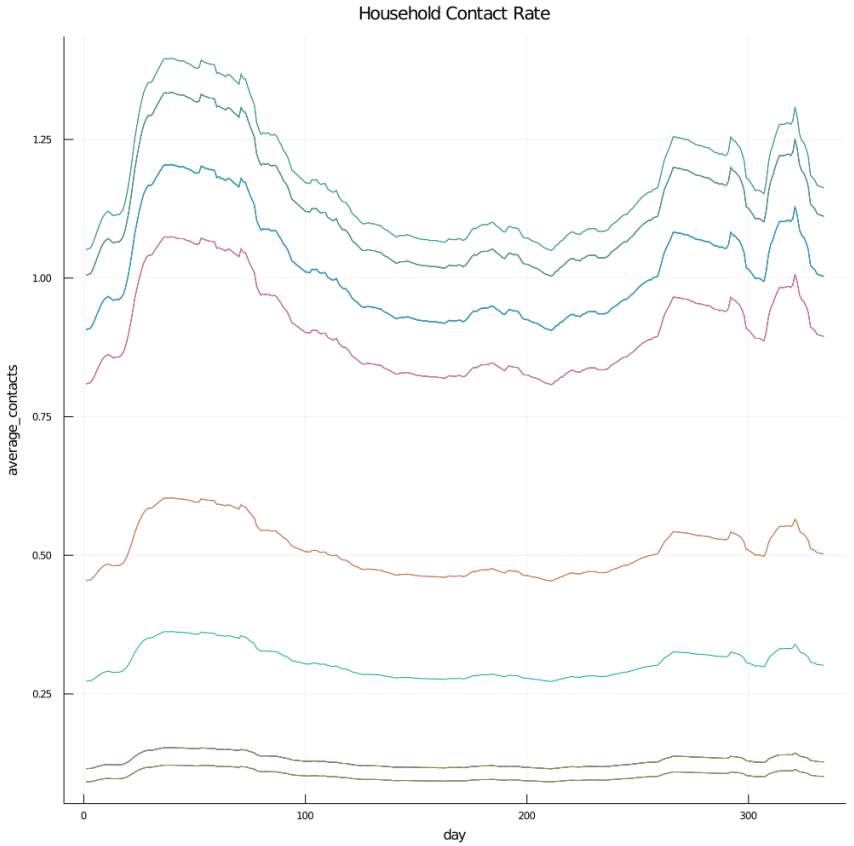




Sources: Arregui et al. (2018), Prem et al. (2020), Mistry et al. (2020)

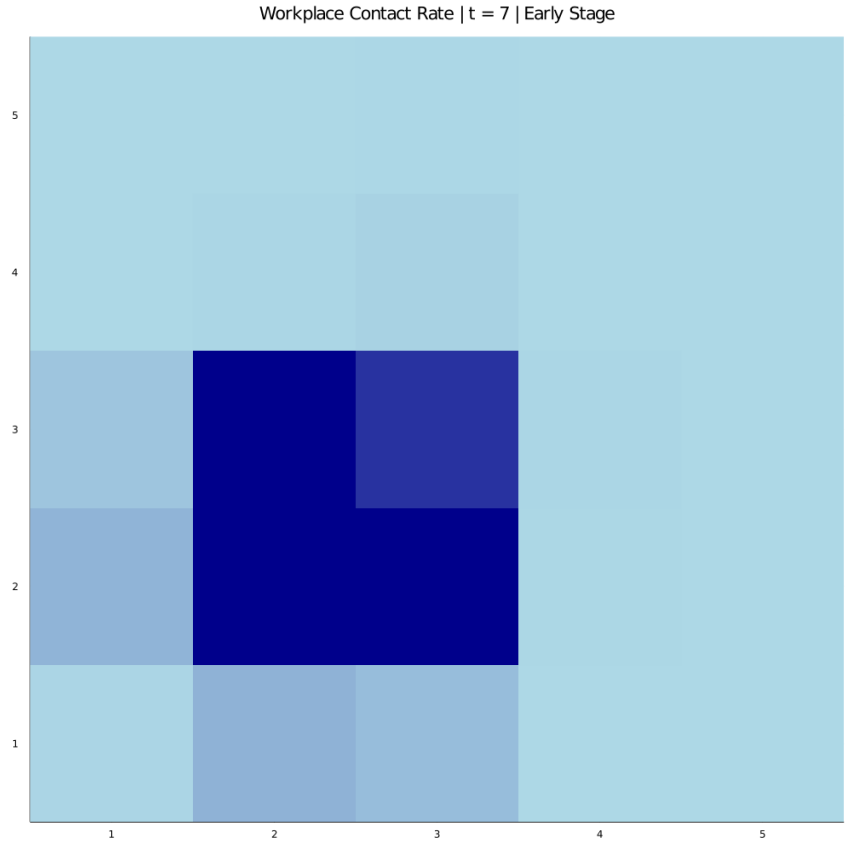
Behavioural Data: Home

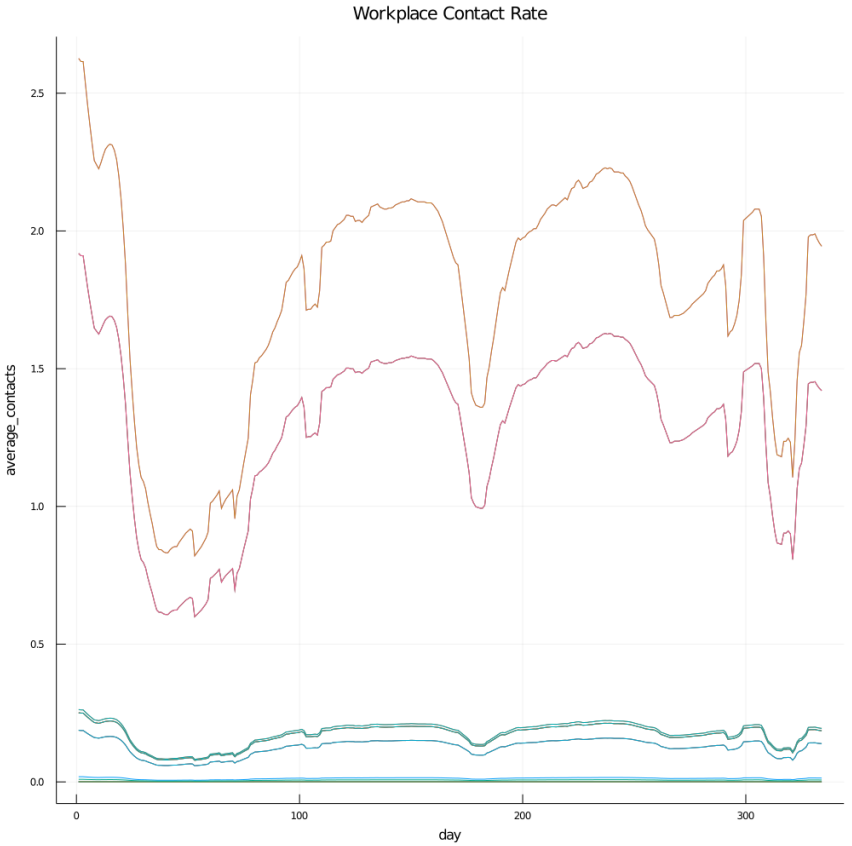




Sources: Prem et al. (2020), Google (2020)

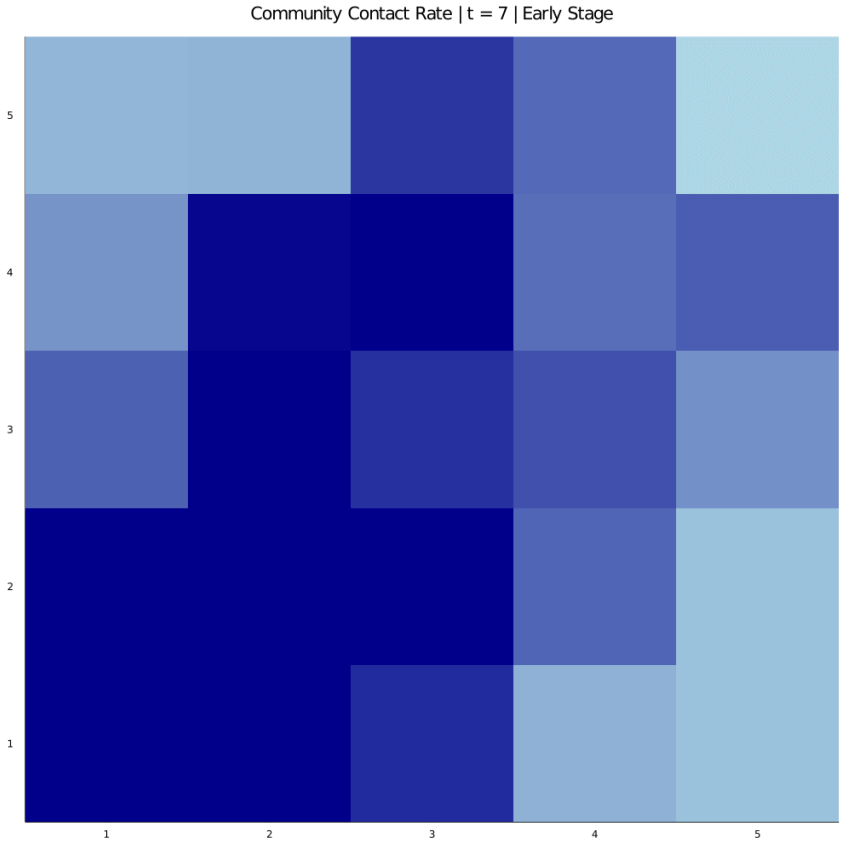
Behavioural Data: Work

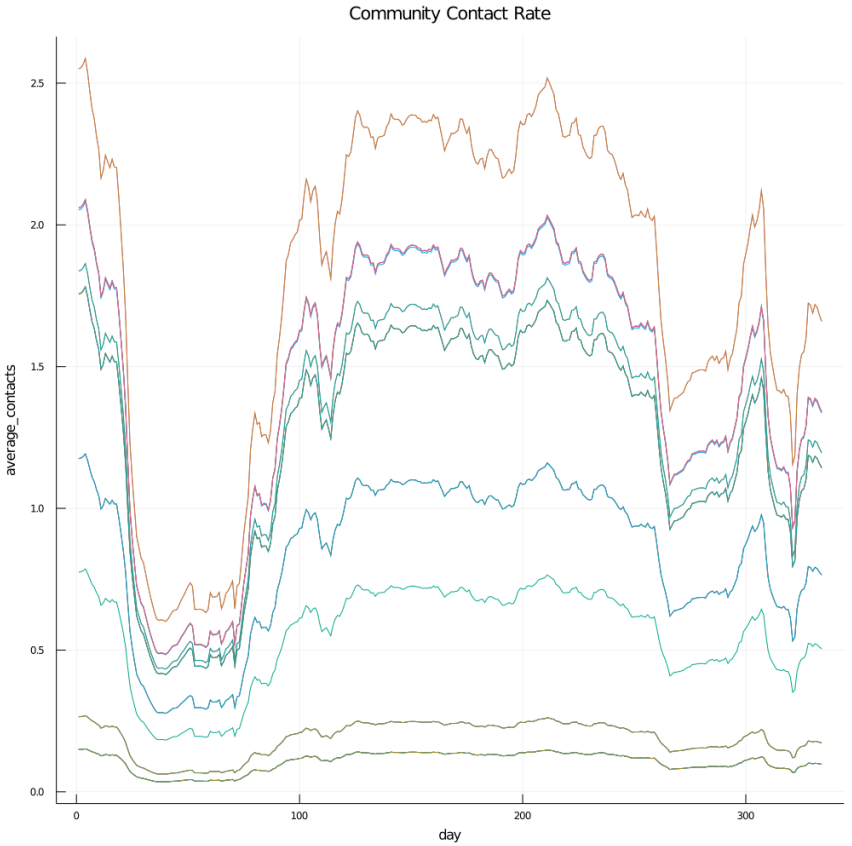




Sources: Prem et al. (2020), Google (2020)

Behavioural Data: Community

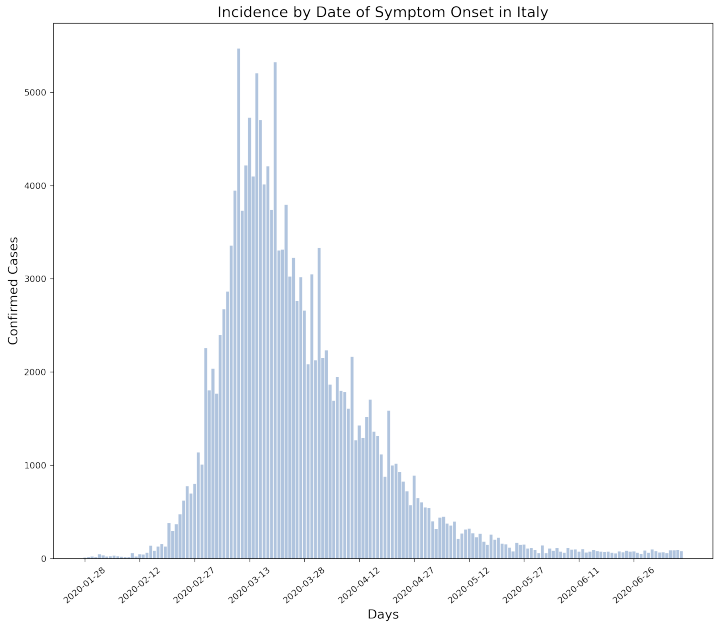




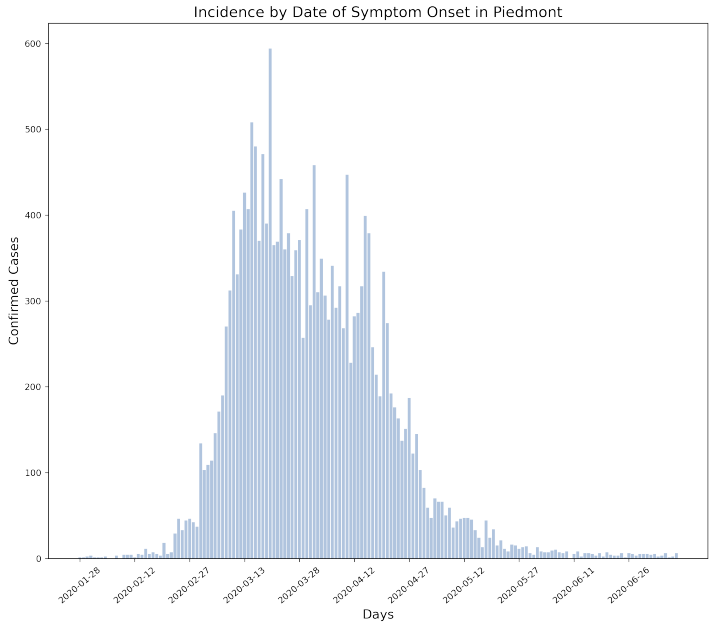
Sources: Prem et al. (2020), Google (2020)

Surveillance Data: Symptoms

National



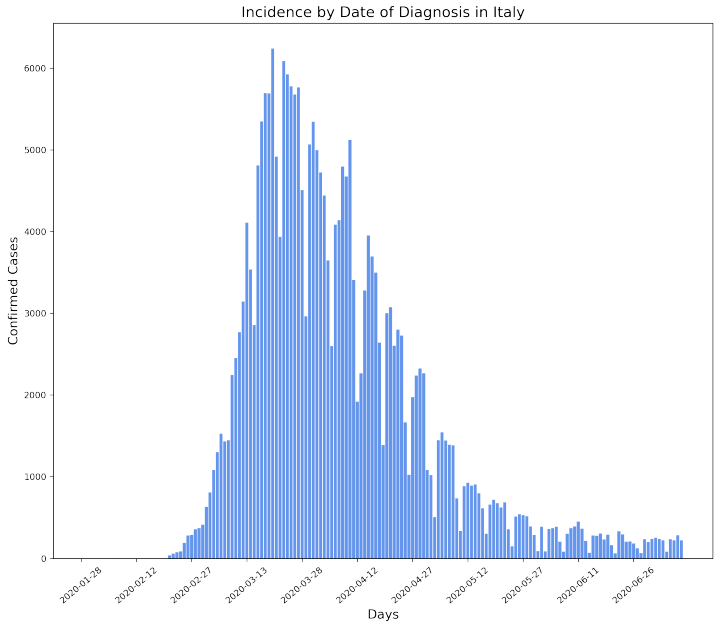
Regional



Sources: PCM-DPC (2020), ISS (2020), SEPI-SEREMI (2020)

Surveillance Data: Diagnosis

National



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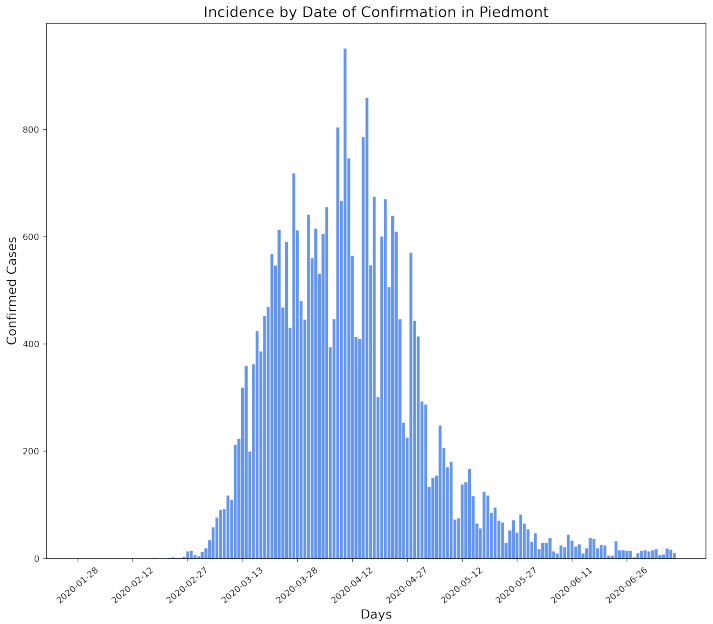
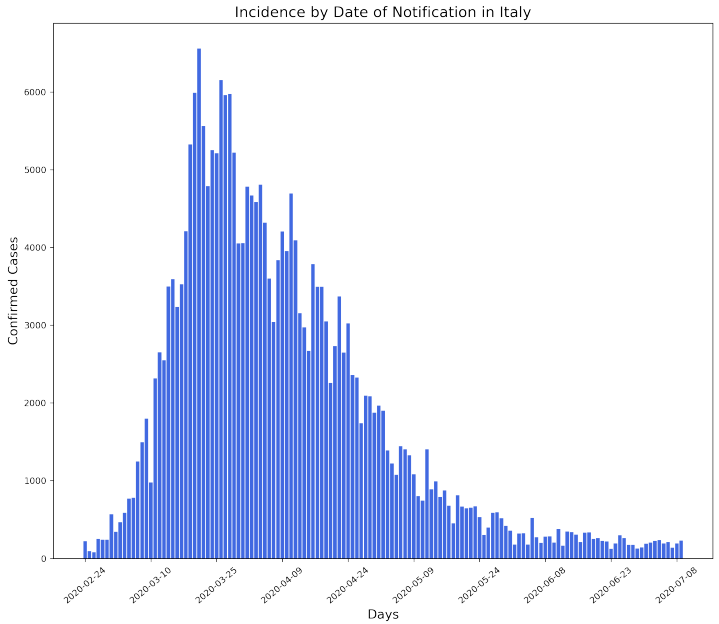


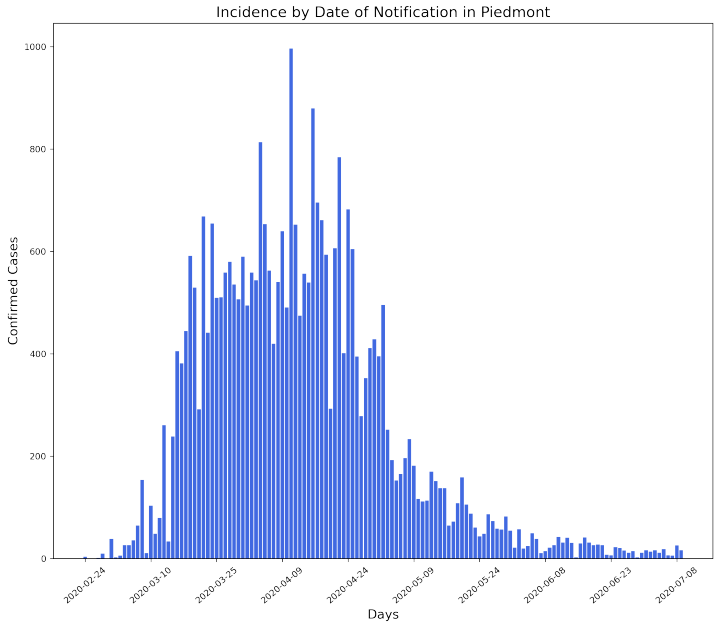
Sources: PCM-DPC (2020), ISS (2020), SEPI-SEREMI (2020)

Surveillance Data: Notification

National



Regional



Sources: PCM-DPC (2020), ISS (2020), SEPI-SEREMI (2020)

Policy Data

Phase	Interventions	Start Date	End Date
1	School Closure	24-02-2020	09-03-2020
2	Weak Lockdown	09-03-2020	22-03-2020
3	Medium Lockdown*	22-03-2020	03-04-2020
4	Strong Lockdown	03-04-2020	04-05-2020
5	Weak Reopening*	04-05-2020	18-05-2020
6	Strong Reopening	04-05-2020	10-07-2020

***Optional phase**: could be contained in "strong lockdown" and "strong reopening" phases respectively.

Source: Regione Piemonte

Model Structure

Model States

Clinical

Variable	Description
S	Susceptible
E	Exposed / Latent
I_p^a	Pre-asymptomatic
I_p^s	Pre-symptomatic
I_a^t	Asymptomatic to be tested
I_s^t	Symptomatic to be tested
I_a^u	Asymptomatic not to be tested
I_s^u	Symptomatic not to be tested
R_u	Undetected recovered
D_u	Undetected deceased
R_t	Tested recovered
D_t	Tested deceased

Surveillance

Variable	Description
T_a	Tested asymptomatic
T_s	Tested asymptomatic
P_a	Confirmed asymptomatic
P_s	Confirmed symptomatic
Q_a	Quarantined asymptomatic
Q_s	Quarantined symptomatic
H	Hospitalized
ICU	Intensive care unit
N_p	Notified/reported confirmed cases
N_q	Notified/reported quarantined cases
N_h	Notified/reported hospitalized cases
N_{icu}	Notified/reported ICU cases
N_r	Notified/reported recovered cases
N_d	Notified/reported deceased cases

Model Parameters

Fixed

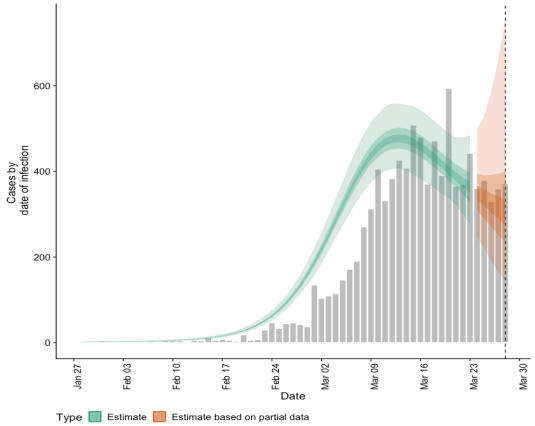
Parameter	Description
θ	Susceptibility to infection
σ	Symptomatic fraction
η	Infection hospitalization ratio
δ	Infection fatality ratio
δ_s	Symptomatic infection fatality ratio
δ_h	Hospitalization fatality ratio
δ_{icu}	Critical care fatality ratio

Free

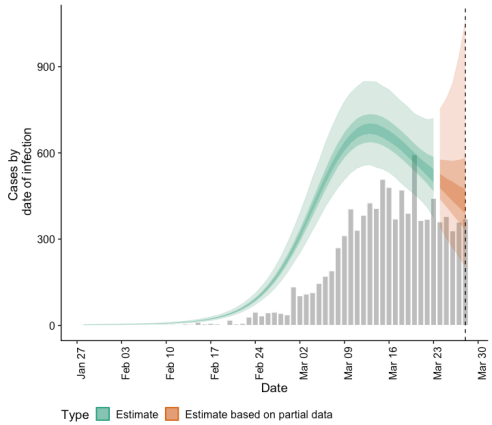
Parameter	Description
$\beta_{p/a/s}$	Transmissibility
$\epsilon_{p/a/s}^{-1}$	Pre- / Infectious period
$\tau_{a/s}$	Ascertainment rate
λ_t^{-1}	Onset to diagnosis
λ_p^{-1}	Diagnosis to confirmation
λ_q^{-1}	Confirmation to isolation
λ_h^{-1}	Confirmation to H admission
λ_{icu}^{-1}	H admission to ICU admission
λ_r^{-1}	Onset to recovery
λ_d^{-1}	Onset to death
λ_{hd}^{-1}	H admission to death
λ_{icud}^{-1}	ICU admission to death
λ_{xn}^{-1}	Notification period

Model Initialization

100% Ascertainment



70% Ascertainment



30% Ascertainment

10% Ascertainment

Model Calibration

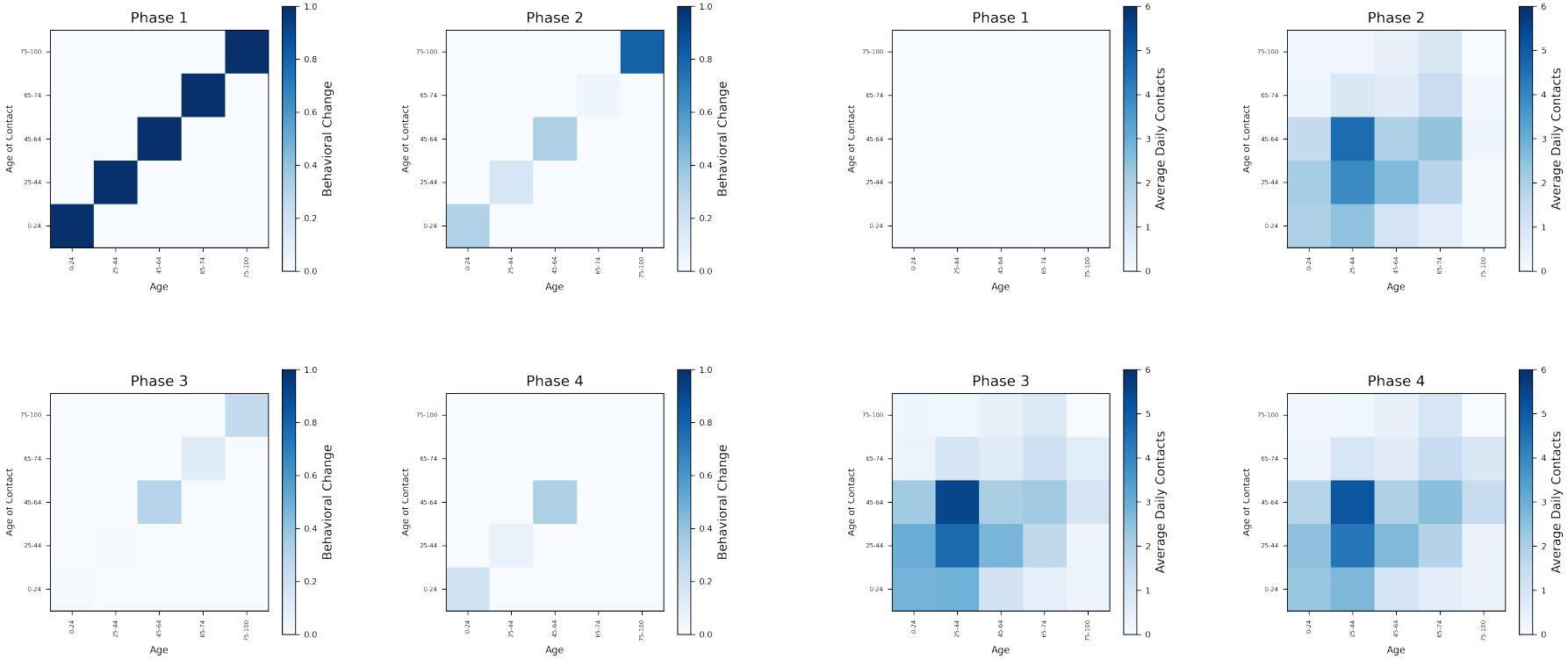
Method	Package	Package Description	Application	Pros	Cons	References
ABC	`ApproxBayes.jl` [1]	Adopts Approximate Bayesian Computation to perform parameters posterior inference	None, implemented for completeness	Very fast sampling	Very inaccurate parameter estimation, expecially for complex models	Sunnåker et al. (2013) & Minter, Retkute (2019)
BFGS	`Optim.jl` [2]	Provides various optimizers and losses to carry out non bayesian (GD-based) optimization	Initialization of more advanced calibration algorithms	Very good optimizer, excellent for initializing the other samplers	Does not produce a posterior, only a set of values.	
MCMC	`Turing.jl` [3]	Exposes a variety of HMC samplers, including the most advanced NUTS	Main parameter estimation tool	Very customizable and easy to use	It suffers from bad priors choiche	Ravenswaaij et al. (2016) & Betancourt (2017)
ADVI	`Turing.jl` [1]	Implements Automatic Differentiation Variational Inference	Main parameter estimation tool	Very quick sampler, and more accurate than ABC. In the future, it could be used to bootstrap the priors to be passed to MCMC methods	Assumes parameters uncorrelation by default	Turing.jl Documentation

[1] Some of its features are used via `DiffEqBayes.jl`
[2] Some of its features are used via `DiffEqParamEstim.jl`
[3] Some of its features are used via `DiffEqBayes.jl` and `DynamicHMC.jl`

Model Calibration

Behaviour

Impact

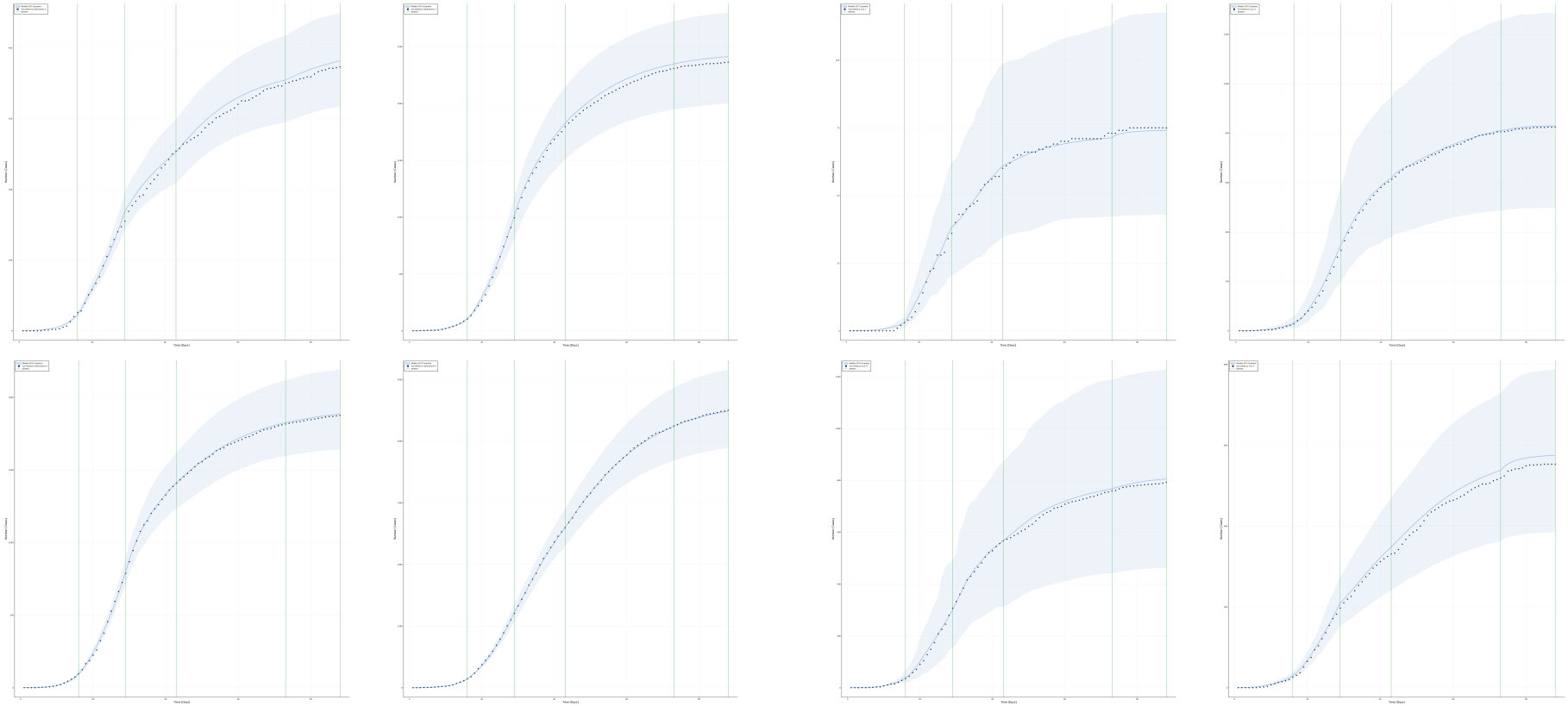


NB: These are simple SEIRD-based estimates for illustrative purposes.

Model Calibration

Hospital Admissions

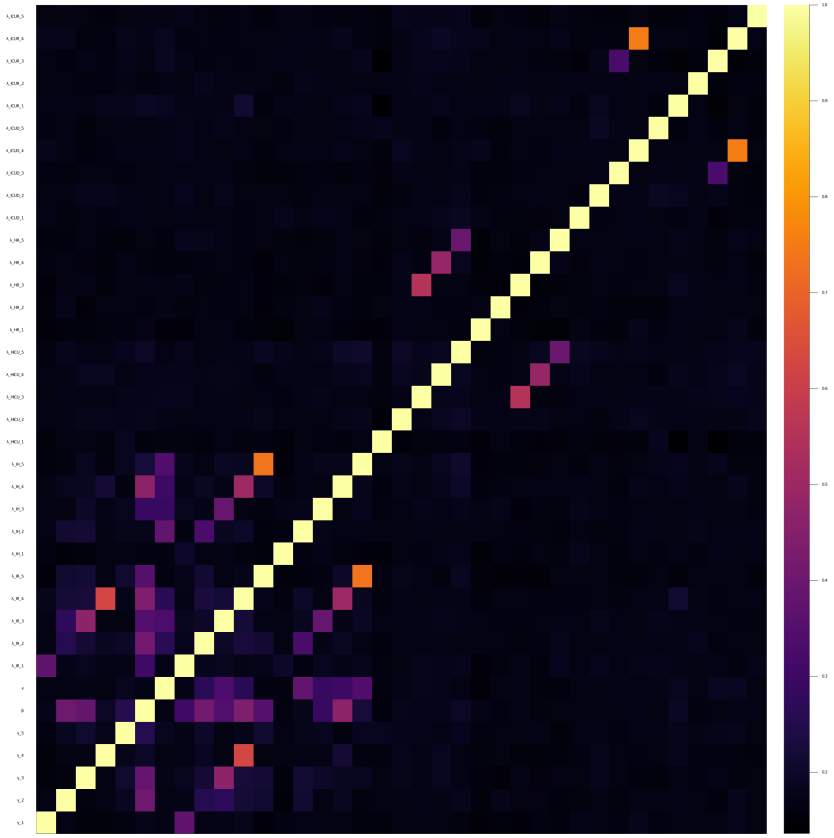
ICU Admissions



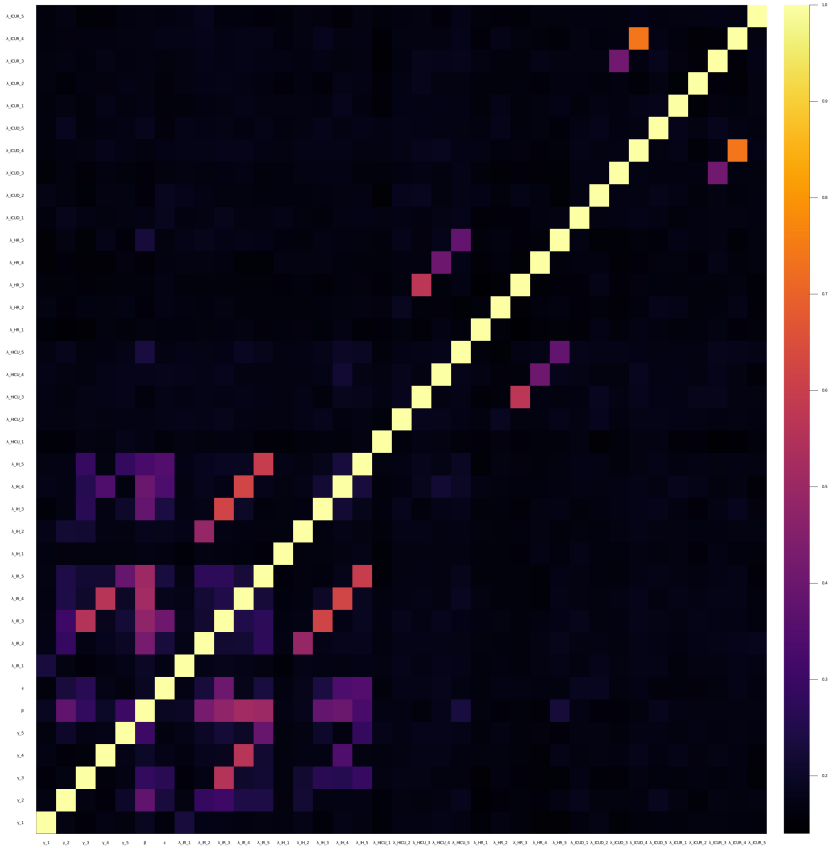
NB: These are simple SEIHICURD-based estimates for illustrative purposes.

Correlation Analysis

School Closure



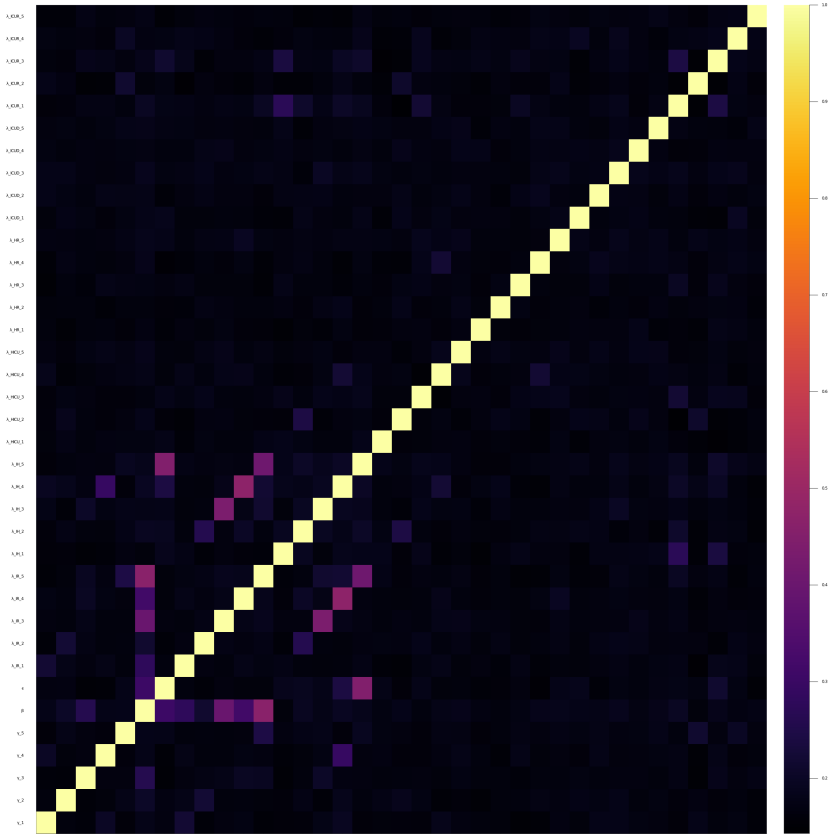
Weak Lockdown



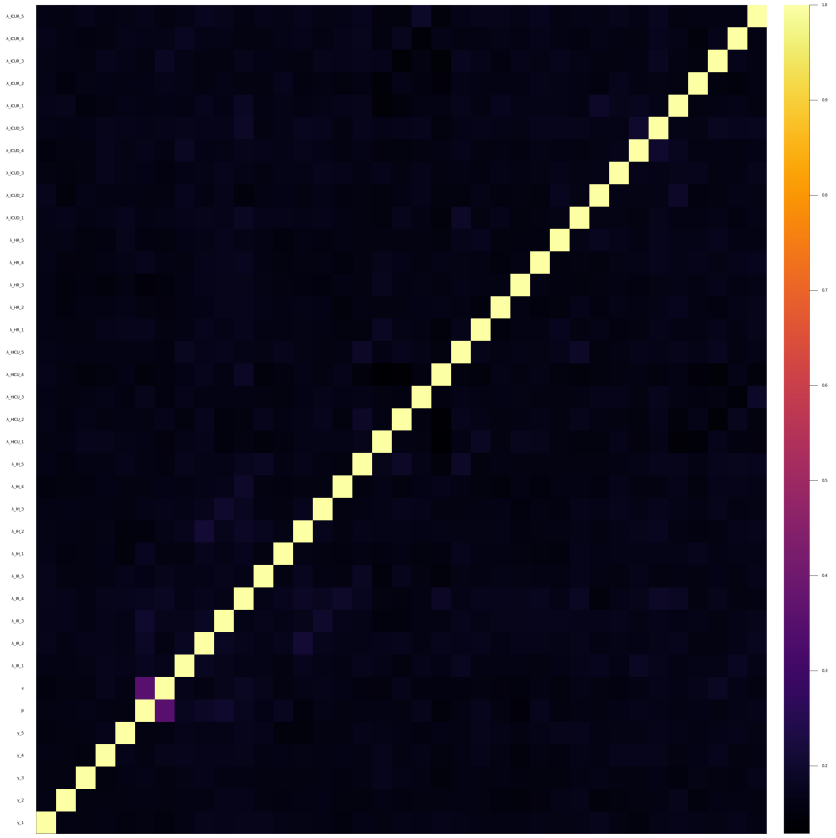
NB: These are simple SEIHICURD-based estimates for illustrative purposes.

Correlation Analysis

Strong Lockdown



Weak Reopening



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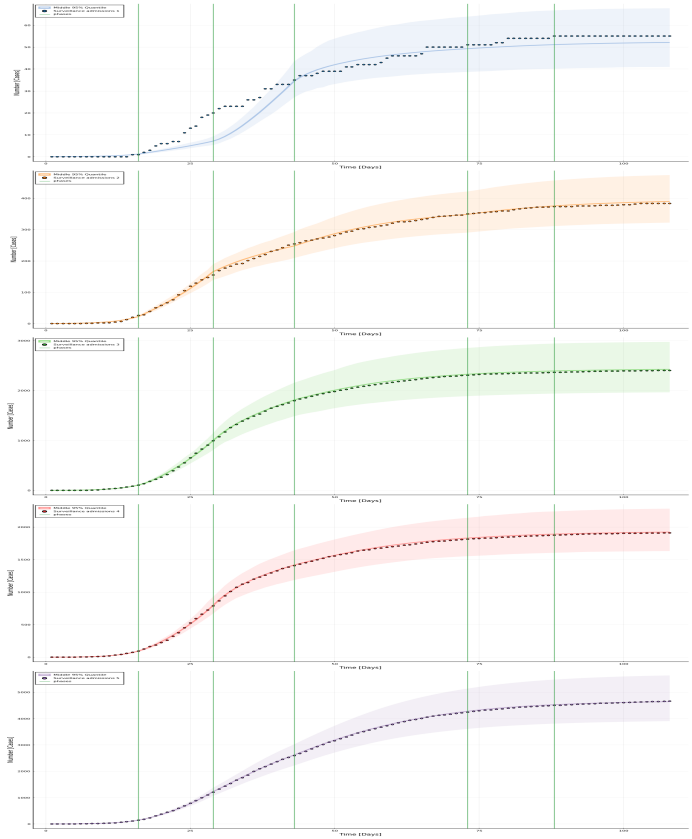
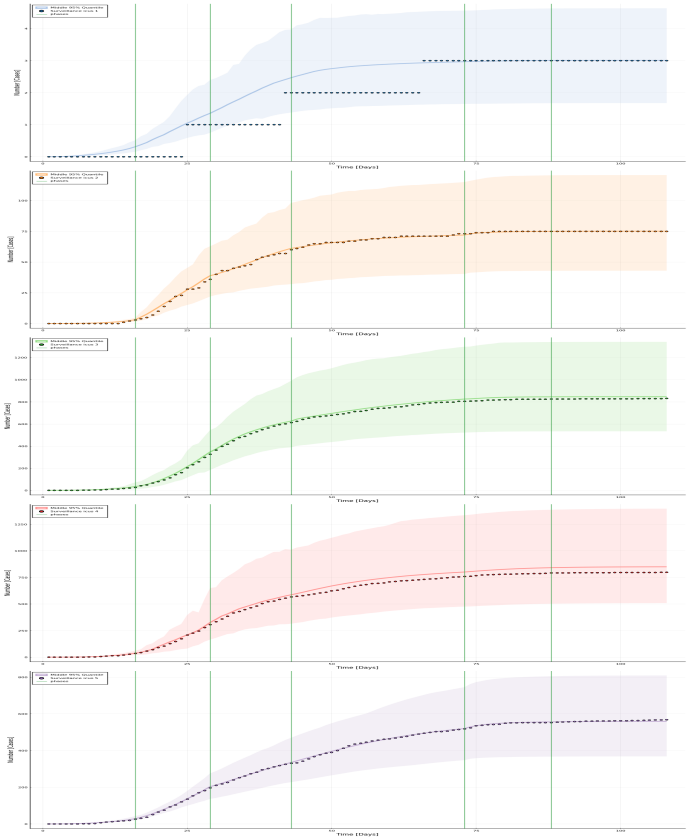
Model Projection

Hospital Admissions



ICU Admissions



NB: These are simple SEIHICURD-based projections for illustrative purposes.

Work in Progress

Rt Estimation

- `{EpiEstim2}` by Thompson et al. (2019)
- `{EpiNow2}` by Abbott et al. (2020)
- $NGM_{eff}(t)$

Identifiability

- Structural identifiability analysis
- Practical identifiability analysis

Sensitivity

- Local sensitivity analysis
- Global sensitivity analysis

Validation

- **Effective Reproduction Number**: simulated incidence based vs. observed incidence based R_t estimation
- **Infections**: simulated infections vs. estimated infections
- **Prevalence**: simulated prevalence vs. observed prevalence (ISTAT (2020))
- **Mortality**: simulated mortality (detected and undetected) vs. observed (ISTAT, ISS) and estimated (Economist, Scortichini et al.) excess mortality

Scenarios

- Retrospective Scenario Analysis
- Prospective Scenario Analysis

Questions

1. Ordinary, intensive and deaths caused by respiratory diseases (e.g. pneumonia) for 2015-2019 and 2020.
2. Line-list data for empirical delay distribution together with event-based `date_notification`.

ID	age	date_onset	date_diag	date_conf	date_in_H	date_out_H	date_in_ICU	date_out_ICU	date_death

3. General update
4. Non-survived ordinary and intensive discharges by date of discharge
5. Finest age classes
6. Both flow and stock hospitalization data
7. Status-stratified confirmed cases by date of diagnosis and by date of confirmation
8. Status-stratified quarantined/isolated cases
9. Dynamics of diagnostic capacity (laboratories and tests)

date	number_laboratories	number_tests

10. Dynamics of ordinary and intensive hospitalization capacity

SEPI-SEREMI (2020)

date	H_bed_capacity	ICU_bed_capacity	medical_personnel