UMC Utrecht

Controlling the pandemic during the SARS-CoV-2 vaccination rollout

Ganna Rozhnova

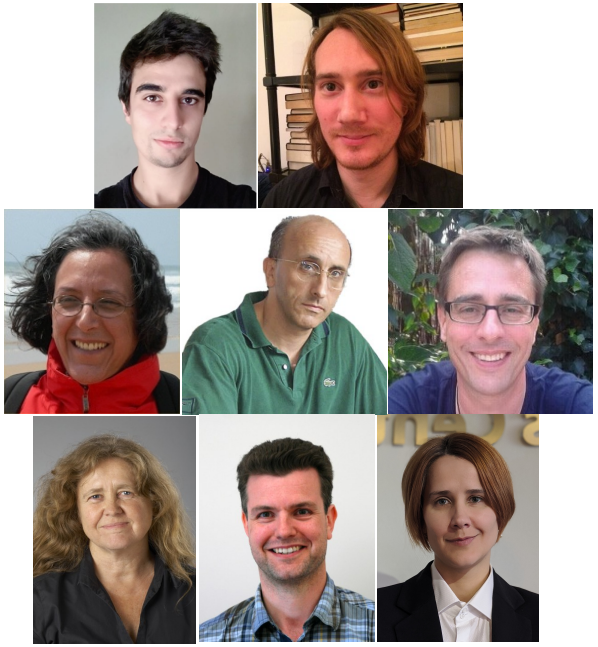
UMC Utrecht, The Netherlands & BioISI, Portugal

Evolutionary Implications of the COVID-19 Vaccination Programme

19 April 2021

Collaborators

- João Viana (Lisbon)
- Christiaan van Dorp (Los Alamos)
- Ana Nunes (Lisbon)
- Manuel Gomes (Lisbon)
- Michiel van Boven (Utrecht)
- Mirjam Kretzschmar (Utrecht)
- Marc Veldhoen (Lisbon)



Making the way out:
model-based evaluation of exit strategies
from the COVID-19 lockdown in Portugal

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Preprint

Research Square

In review in *Nature Communications*

Viana J, van Dorp C, Nunes A, Gomes M, van Boven M, Kretzschmar M, Veldhoen M, Rozhnova G (2021). Controlling the pandemic during the SARS-CoV-2 vaccination rollout: a modeling study
https://doi.org/10.21203/rs.3.rs-358417/v1

GitHub https://github.com/lynxgav/COVID19-vaccination

medRxiv
THE PREPRINT SERVER FOR HEALTH SCIENCES

CSH Cold Spring Harbor Laboratory BMJ Yale

Controlling the pandemic during the SARS-CoV-2 vaccination rollout: a modeling study

João Viana, Christiaan H. van Dorp, Ana Nunes, Manuel C. Gomes, Michiel van Boven, Mirjam E. Kretzschmar, Marc Veldhoen, Ganna Rozhnova

doi: https://doi.org/10.1101/2021.03.24.21254188

Abrir portas onde se erguem muros Director: Manuel Carvalho **Quarta-feira, 7 de Abril de 2021** • Ano XXXII • n.º 11.303 • Edição Lisboa • Assinaturas 808 200 095 • **1,30€**

JOSÉ ALVES

Operação Marquês
Quando se fala de corrupção, portugueses lembram-se de Sócrates e de Salgado

Sociedade, 14/15 e Editorial

Leia mais em **publico.pt/operacao-marques**

Ritmo de vacinação e reabertura total das escolas podem levar a quarta vaga

Média de contactos diários na população pode atingir níveis semelhantes aos do Outono passado

O ritmo previsto de vacinação contra a covid-19 não é suficiente para controlar a pandemia em Portugal. Os autores de um estudo que avalia o impacto do aligeiramento das medidas de controlo, a par da campanha de vacinação em curso, afirmam que se o alívio das restrições incluírem a reabertura total das escolas e dos espaços interiores de bares e restaurantes, é provável que a média de contactos diários atinja níveis similares aos do Outono passado e, consequentemente, ocorra nova vaga de hospitalizações Destaque, 2 a 4

Teletrabalho
Sindicatos exigem despesas na lei, patrões querem acordos

Confederações sindicais e patronais estão divididas quanto à forma como a lei deve regular as despesas do teletrabalho Economia, 26

Apoios do Estado
Governo desafia oposição a mudar lei sobre independentes

Executivo defende que o texto aprovado se traduz num apoio mais difícil de concretizar e que prejudicará "muitas pessoas" Economia, 27

EUA
Estrela dos republicanos sob suspeita de tráfico sexual

Matt Gaetz, um dos favoritos de Trump, terá mantido uma relação com uma menor e pode vir a ser acusado de tráfico sexual Mundo, 19

Background

- Portugal experienced three waves of COVID-19
- Vaccination started at the end of December 2020
- Struggle to choose the right mix of measures to keep COVID-19 under control but to allow for social and economic activity

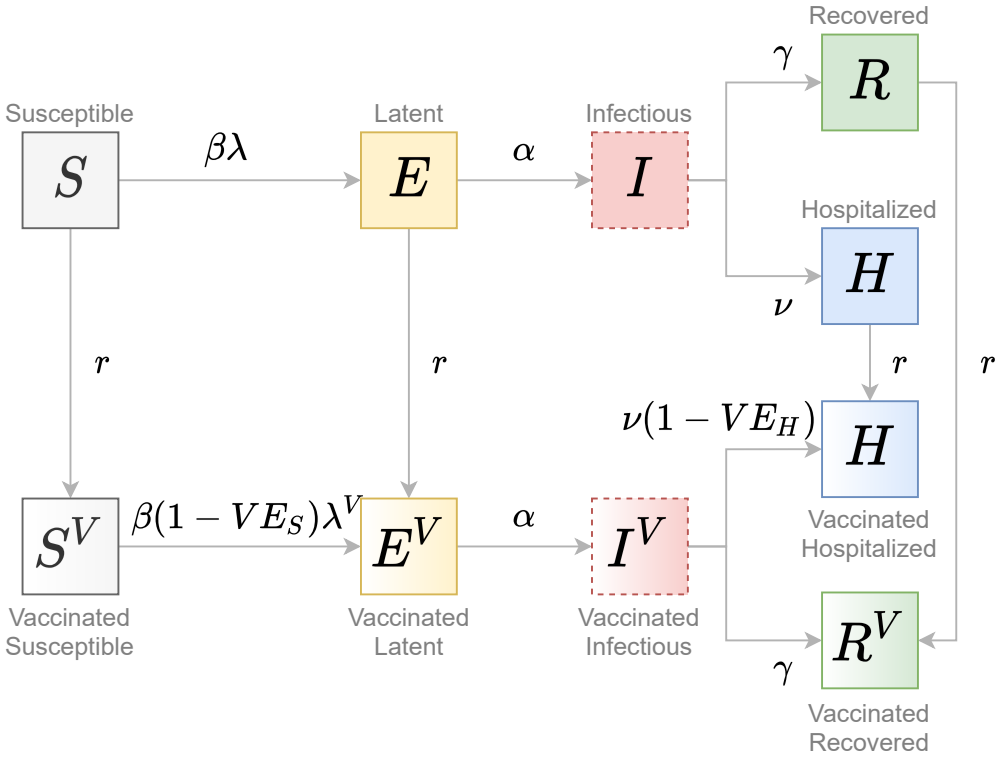
Objectives

- What is the impact of vaccination on the transmission dynamics of SARS-CoV-2 in Portugal?
- When and which control measures can be relaxed as the vaccination is rollout in 2021?
- How are predictions affected if vaccine efficacy was reduced due to antigenic escape variants?

Moore et al. *Lancet Infectious Diseases*. 18 March 2021.
doi: 10.1016/S1473-3099(21)00143-2

Scientific Advisory Group for Emergencies. Report. 18 February 2021.

Transmission model



Age-specific parameters

- β - susceptibility
- λ, λ^V - forces of infection
- ν - hospitalization rate
- r - vaccination rate

Constant parameters

- $1/\alpha$ - latent period
- $1/\gamma$ - infectious period
- VE_S - vaccine efficacy in reducing susceptibility
- VE_I - vaccine efficacy in reducing infectivity (not shown)
- VE_H - vaccine efficacy in preventing hospitalization/death

- 10 age classes/hospitalization classes/vaccination classes
- 3 susceptibility classes (Jing et al. *Lancet Inf Dis* 2020; Goldstein et al. *JID* 2020)
- 5 seroprevalence classes

Data & Fitting

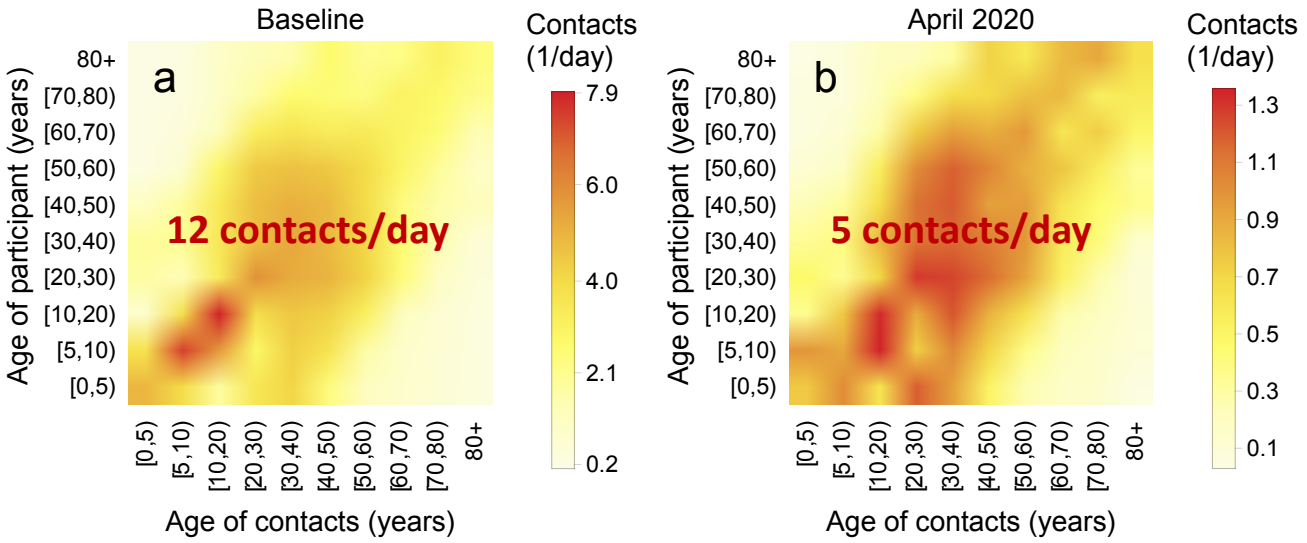
The model is fitted to two data sets

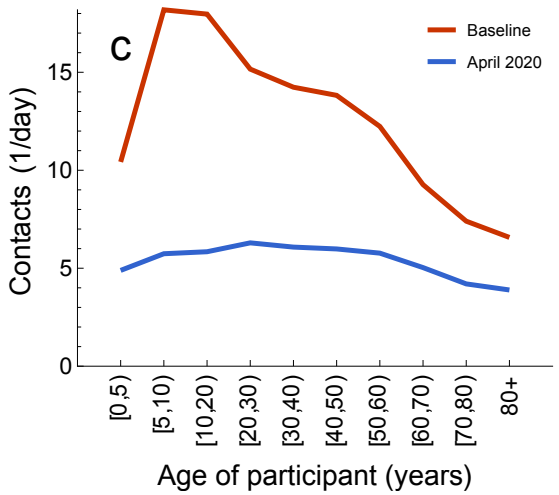
- **Data 1**: age-stratified hospital admissions (n = 28,482)
- Period: 325 days after the first case (2 March 2020 – 15 January 2021)
- Start of the epidemic: 26 February 2020
- **Data 2**: Age-stratified serological data (n = 2,301)
- Date: 28 May 2020

- Bayesian framework using Stan with R interface
- 32 parameters are estimated

Rozhnova et al. *Nature Communications* 12, 1614 (2021) Model-based evaluation of school- and non-school-related measures to control the COVID-19 pandemic.

Contact patterns





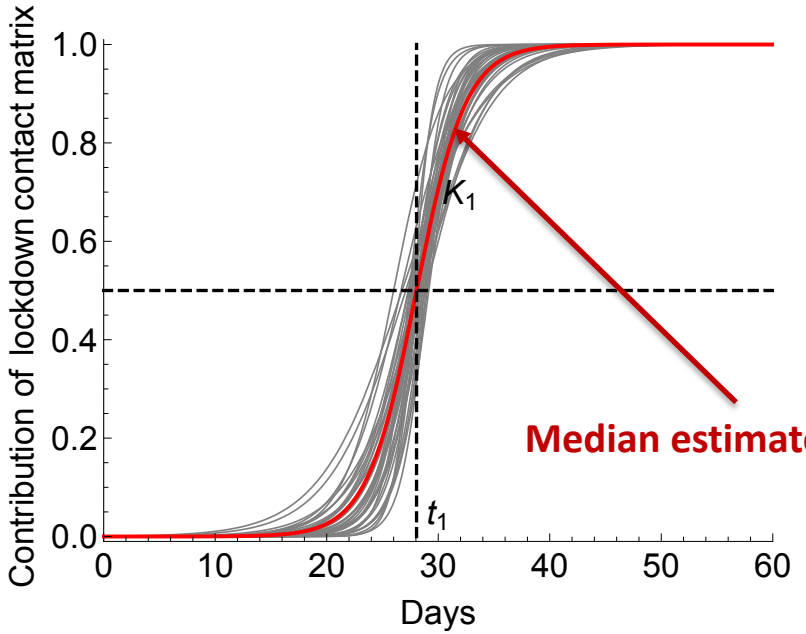
60% reduction in contacts

Mistry et al. *Nat Com* 12, 323 (2021)
Backer et al. *Eurosurveilance* 26 (2021)

First lockdown transition

We use a linear combination of matrices before and after lockdown

$$c_{kl} = [1 - f(t)]b_{kl} + \zeta_1 f(t) a_{kl} \qquad f(t) = \frac{1}{1 + e^{-K_1(t-t_1)}}$$

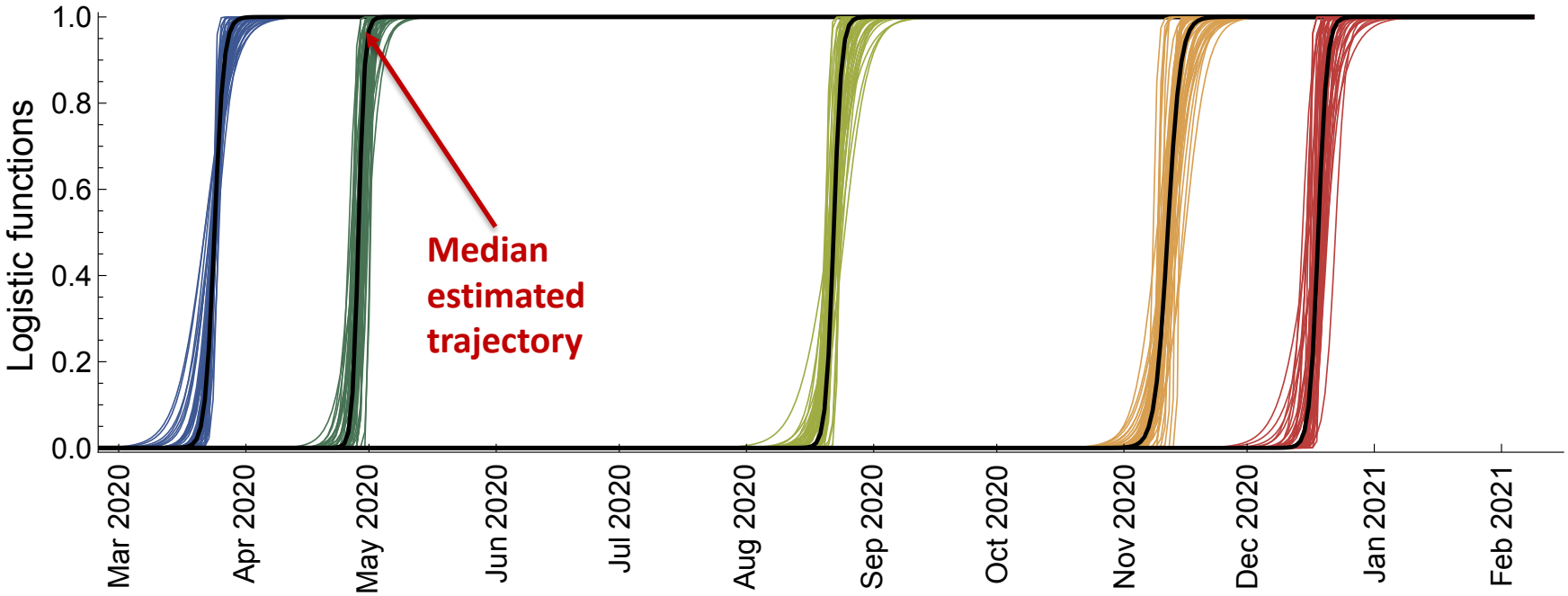


Speed K_1 and timing t_1 of the transition in the contact patterns are estimated

Median estimated trajectory

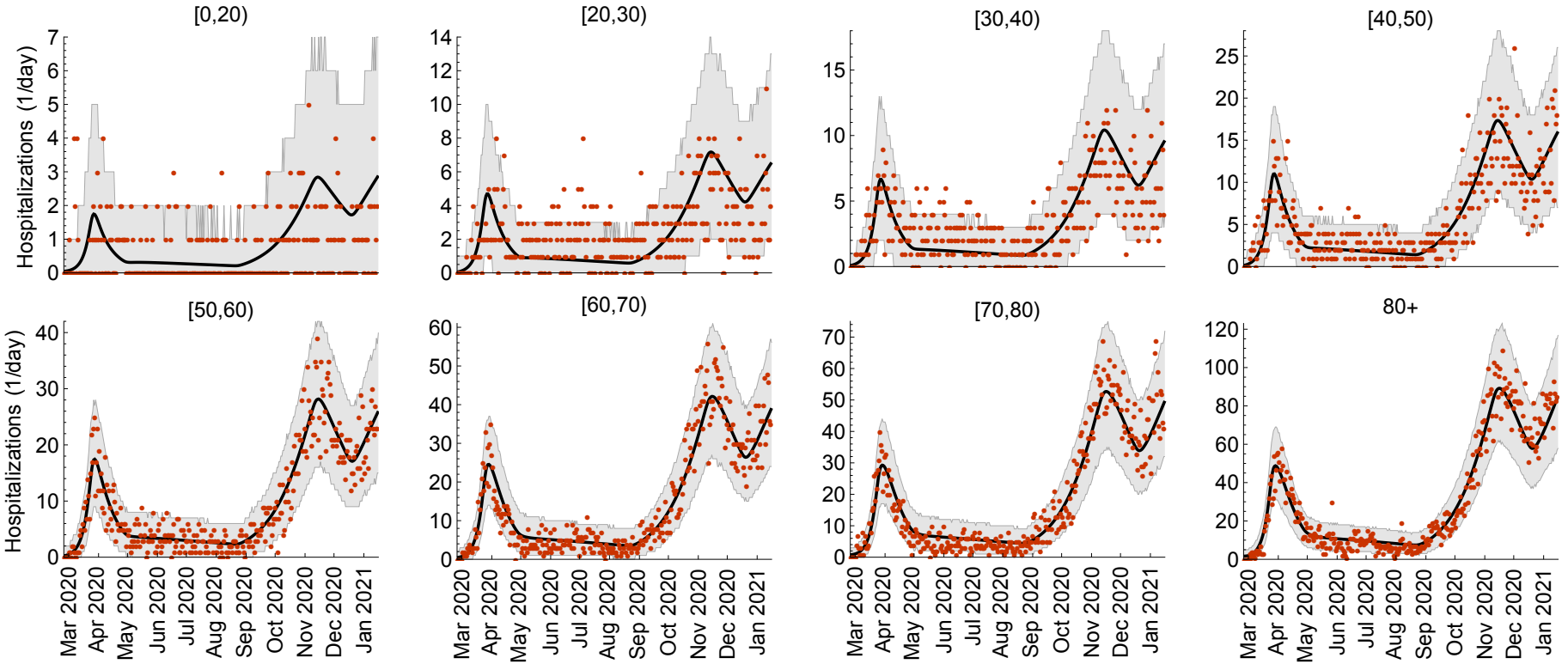
Rozhnova et al. *Nature Communications* 12, 1614 (2021) Model-based evaluation of school- and non-school-related measures to control the COVID-19 pandemic.

Time-varying contact patterns



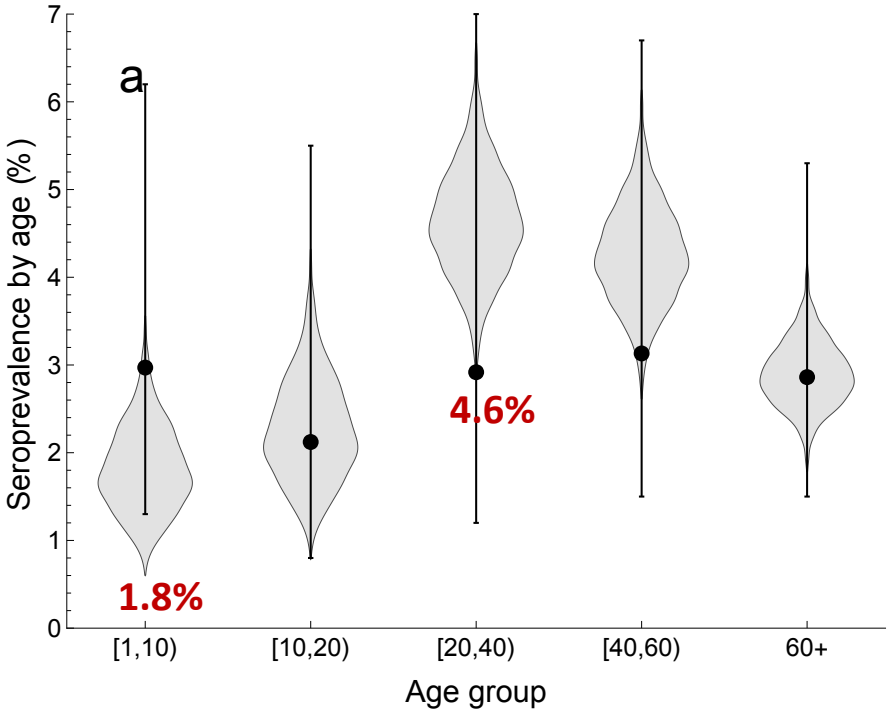
- First lockdown/1st Emergency State
- Relaxation of measures
- Further relaxation of measures (school opening)
- 2nd Emergency State
- Relaxation due to Christmas/New Year holidays

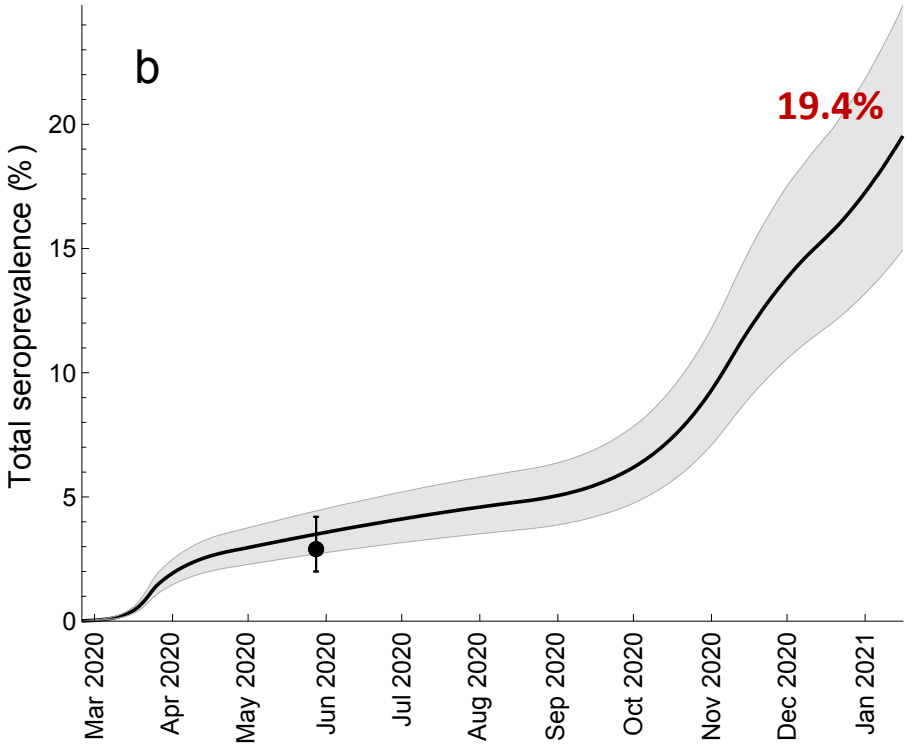
Model fit: Hospital admissions



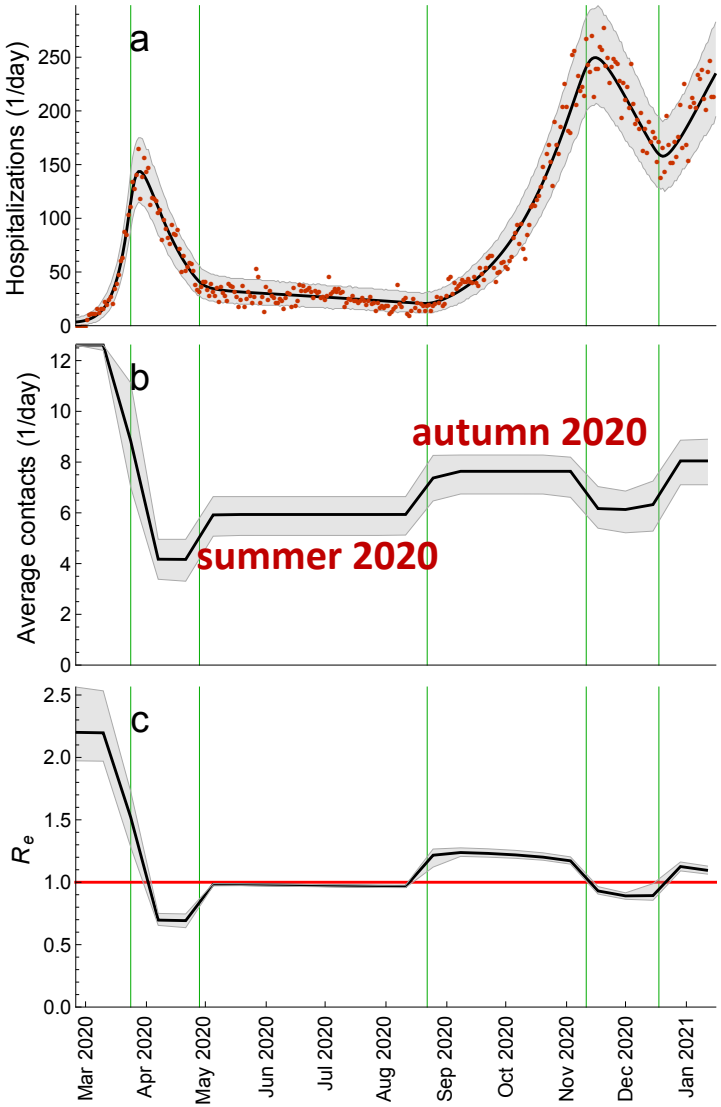
- 1st wave, low epidemic activity, 2nd & 3rd waves

Model fit: Seroprevalence





Time-varying contact patterns & $R_e(t)$



- $R_e(t)$ is calculated using the estimated level of seroprevalence
- $R_e(t) < 1$ & control measures in place

  partial control
- $R_e(t) < 1$ & pre-pandemic contacts

  full control

Vaccination program

Table 1. The Portuguese vaccination plan.

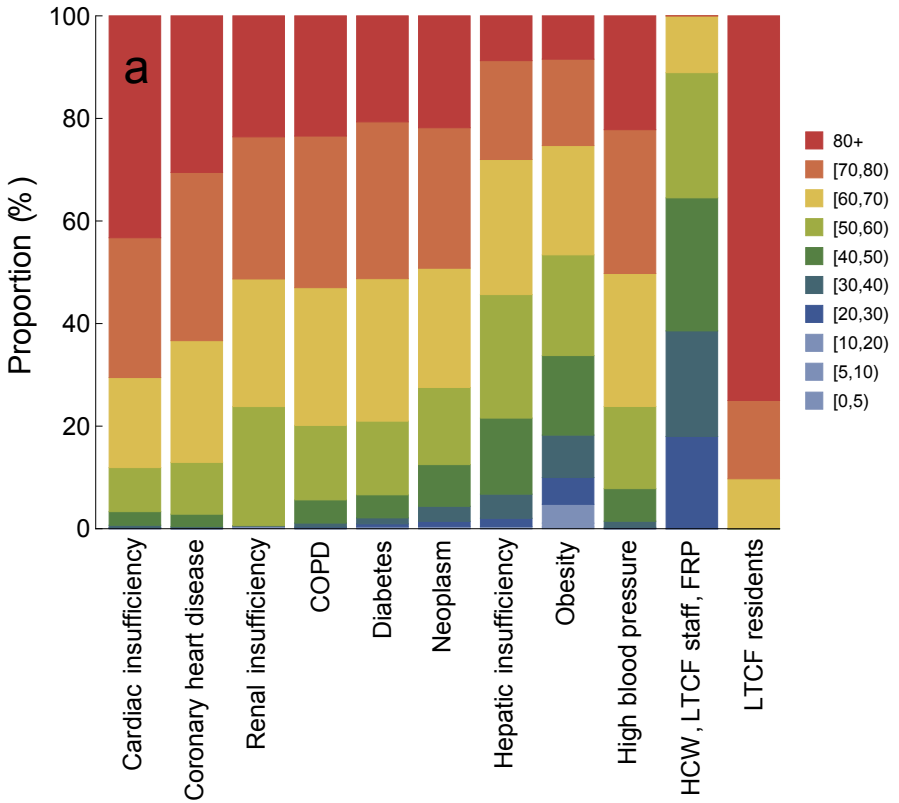
Category	Age (years)	Vaccination period	Persons
Phase 1			**937,361**
Healthcare workers (HCW)	20 – 65	27 Dec 2020 – 28 Feb 2021	199,708
Long-term care facilities (LTCF)		01 Jan 2021 – 28 Feb 2021	148,119
Residents	65+		86,982
Staff	20 – 65		61,138
Risk Group 1	50+	01 Feb 2021 – 30 Apr 2021	513,634
Cardiac insufficiency			207,571
Coronary heart disease			169,265
Renal insufficiency			8,201
Chronic obstructive pulmonary disease (COPD)			128,597
First response professionals (FRP) (firemen, police, military etc.)	20 – 65	01 Feb 2021 – 30 Apr 2021	75,900
Phase 2			**3,333,191**
Persons with or without morbidities unvaccinated before*	65+	01 May 2021 – 31 Jul 2021	1,873,349
Risk Group 2	50 – 65	01 May 2021 – 31 Jul 2021	1,459,842
Diabetes			222,864
Neoplasm			114,246
Hepatic insufficiency			93,004
Chronic kidney disease			4,222
Obesity			392,959
High blood pressure			632,547
Phase 3			**6,529,448**
Remaining persons (excluding children)**	20 – 65	01 Aug 2021 – 31 Dec 2021	6,529,448
Total*			10,800,000

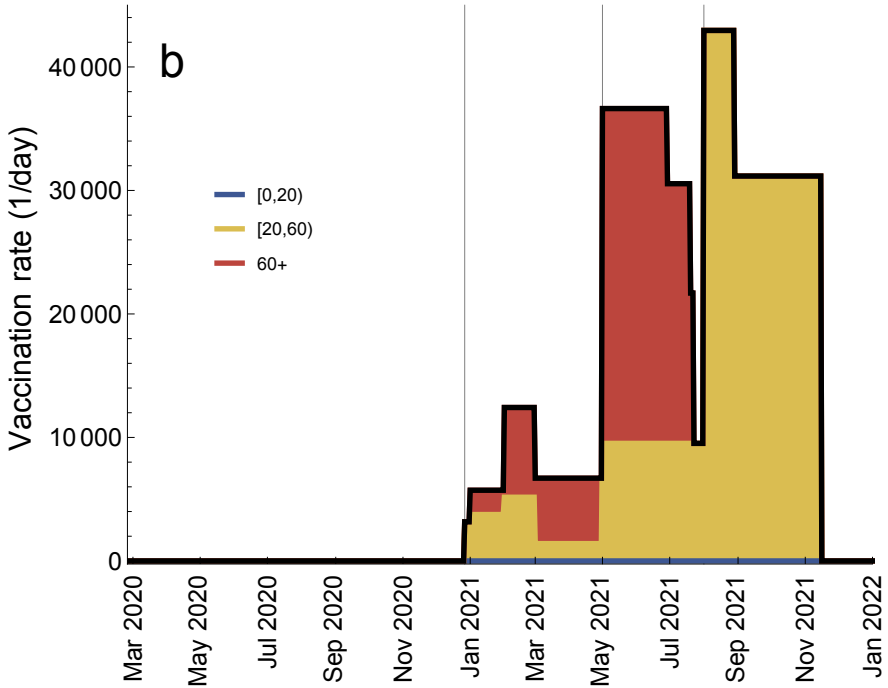
*The Portuguese vaccination plan assumes that all persons in the population will be vaccinated with a two-dose vaccine schedule. In the model, the maximum vaccination coverage in any age group is 90%. **According to the current guidelines, persons under 18 years old are not eligible for vaccination. In the model, we assumed that the age group of 0 to 20 years old is not vaccinated.

Vaccination analyses

- Maximum vaccination coverage of 90% (Makhoul et al. *Vaccines* 2021)
- Persons under 20 years of age are not vaccinated
- Vaccine efficacies for Pfizer vaccine (96% of total doses)
- Infection-blocking properties
- Vaccination is a single event conferring protection equivalent to 2 vaccine doses
- Optimistic and pessimistic sets of vaccine efficacies (94% vs 55% efficacy in reducing susceptibility; Thompson et al. *CDC* 2021; Moustsen-Helms et al. *medRxiv* 2021; Chodick et al. *medRxiv* 2021)
- There is (no) behavior compensation in vaccinated persons

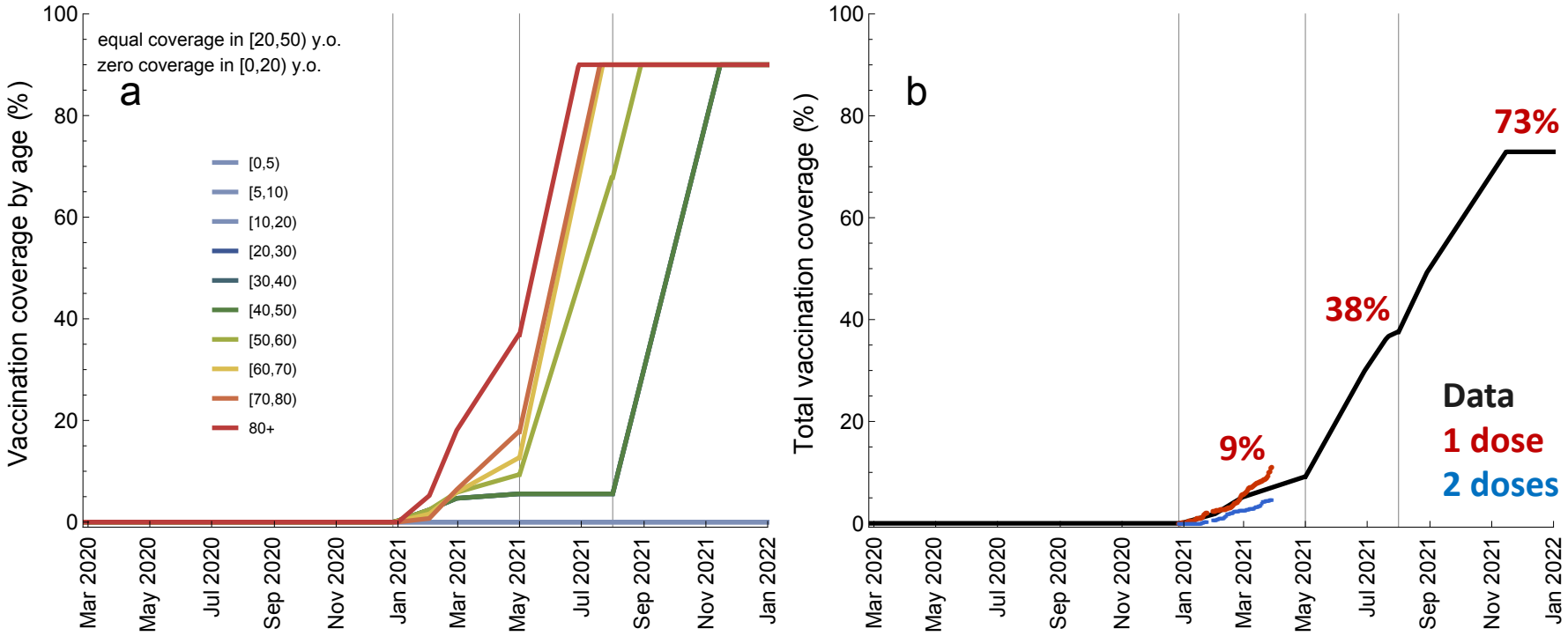
Vaccination rollout schedule





- Morbidities in the vaccination plan are defined by ICPC-2 codes
- Data on the age distribution of morbidities from the Ministry of Health

Vaccination coverage

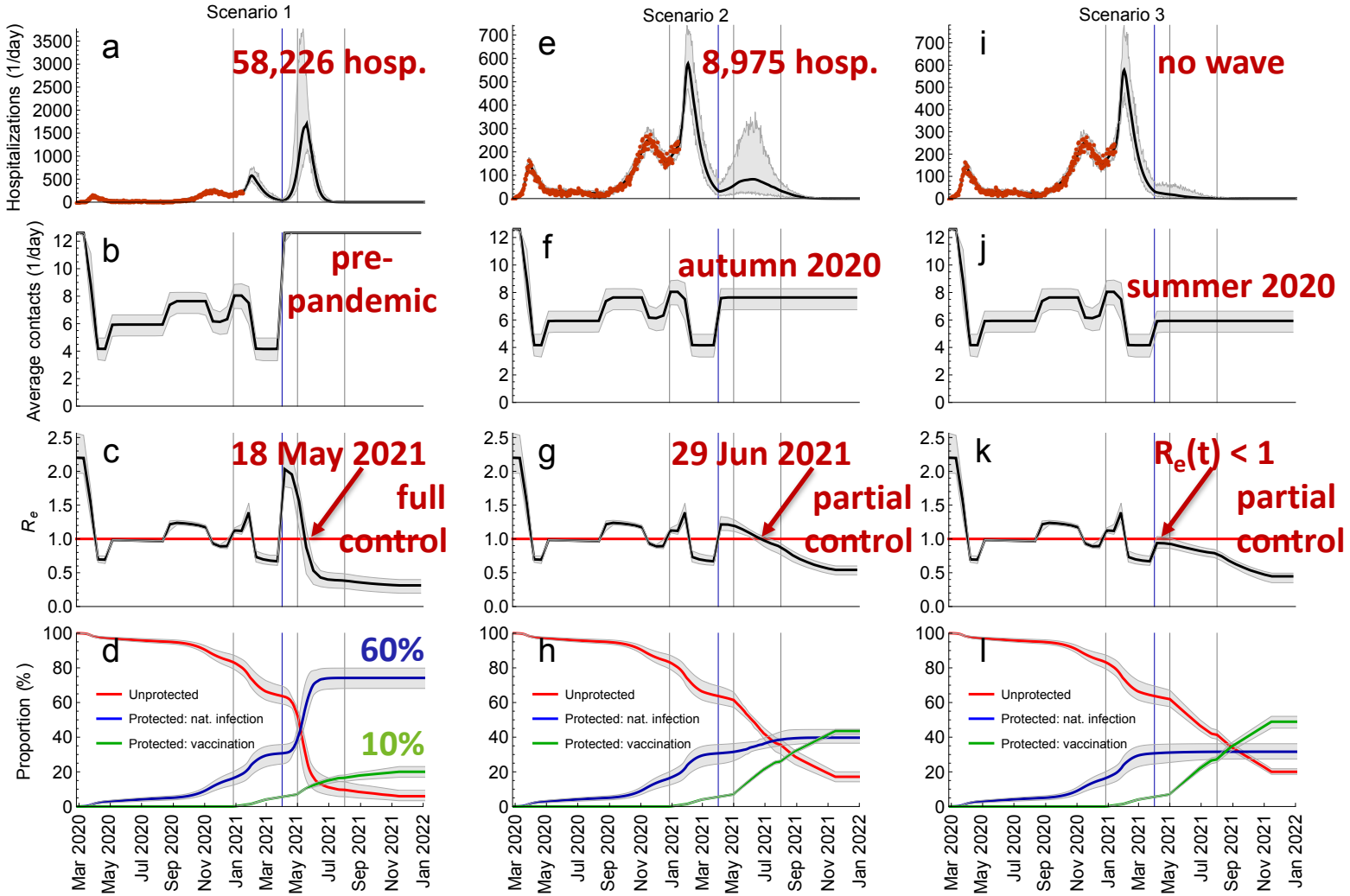


- 80+ -> end of June 2021
- [60,80) -> 3rd week of July 2020
- [50,60) -> end of August 2021
- [20,50) -> mid-November 2021

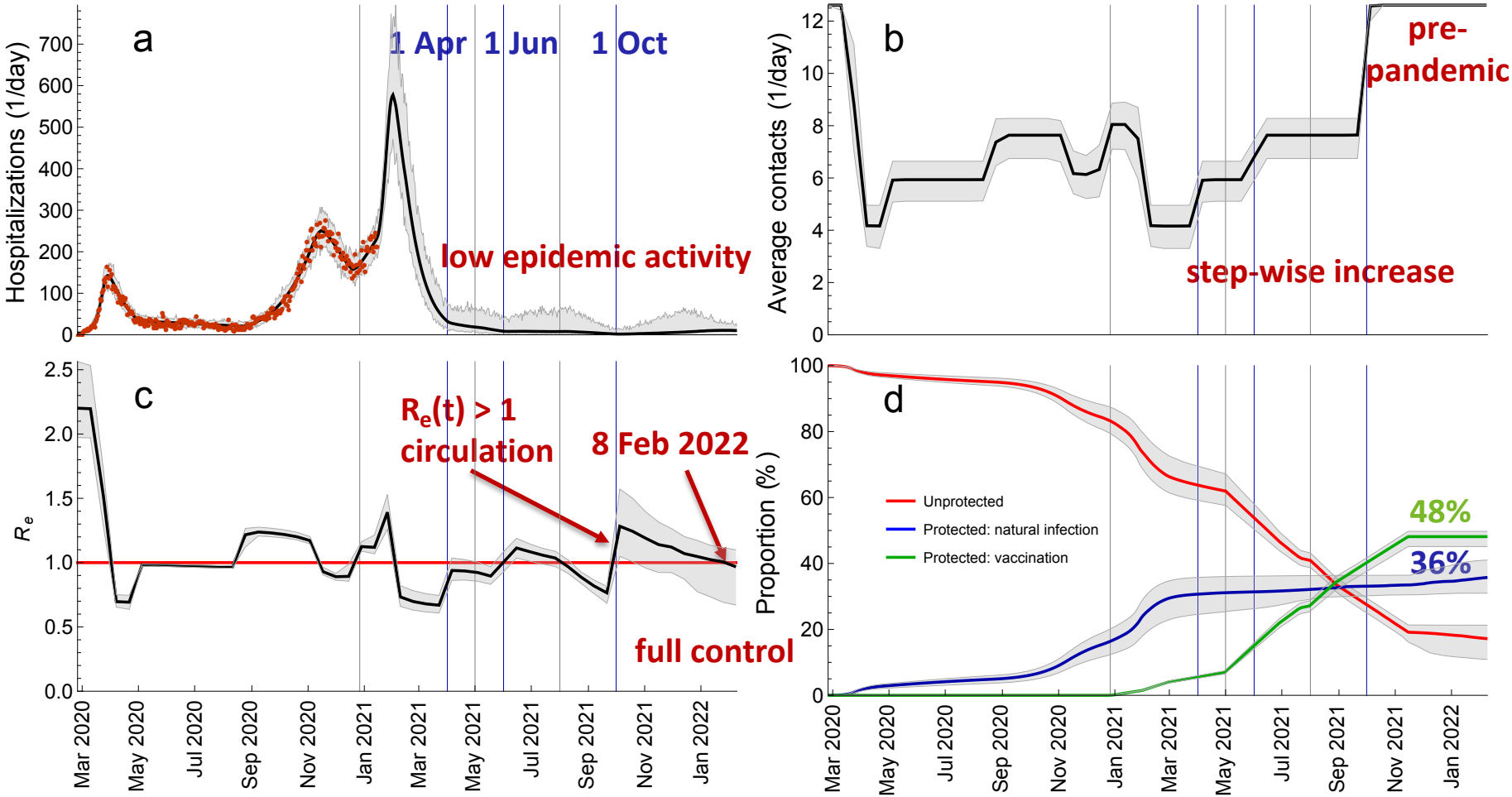
Relaxation scenarios

- **Scenario 1** Lifting all measures
- **Scenario 2** Partial lifting of measures as in autumn 2020
- **Scenario 3** Partial lifting of measures as in summer 2020
- **Scenario 4** Step-wise relaxation of measures

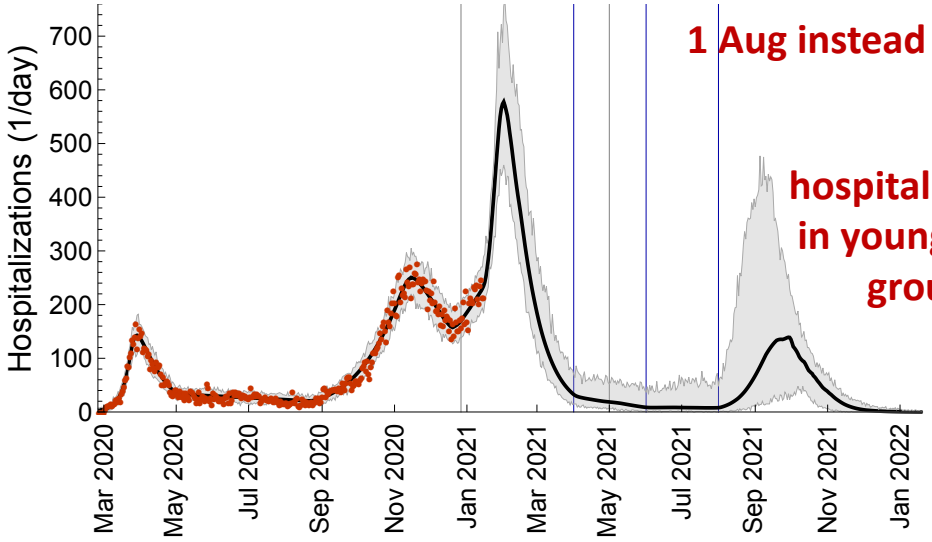
Scenarios 1, 2, 3



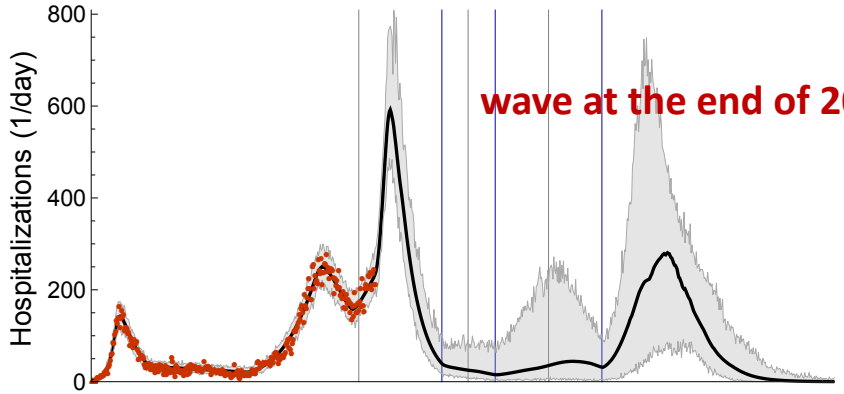
Scenario 4: Step-wise relaxation



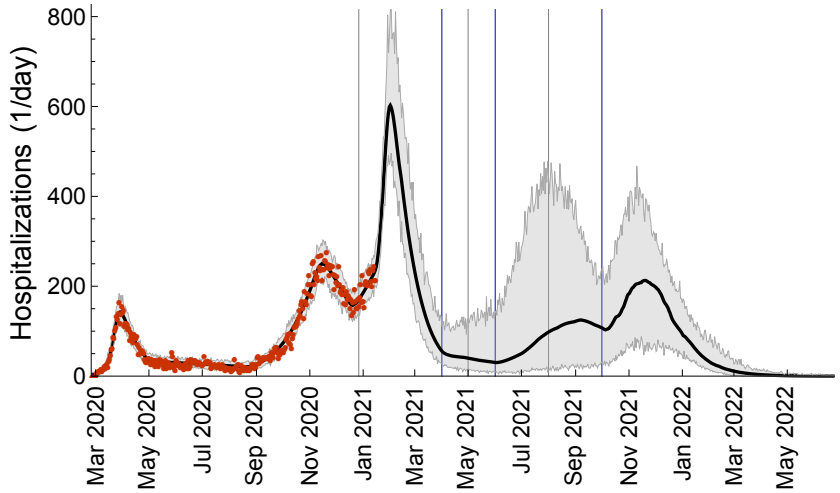
Scenario 4: Different timing



Scenario 4: Pessimistic assumptions



Decreased vaccine efficacy due to antigenic escape variants Zhou et al Cell 2021



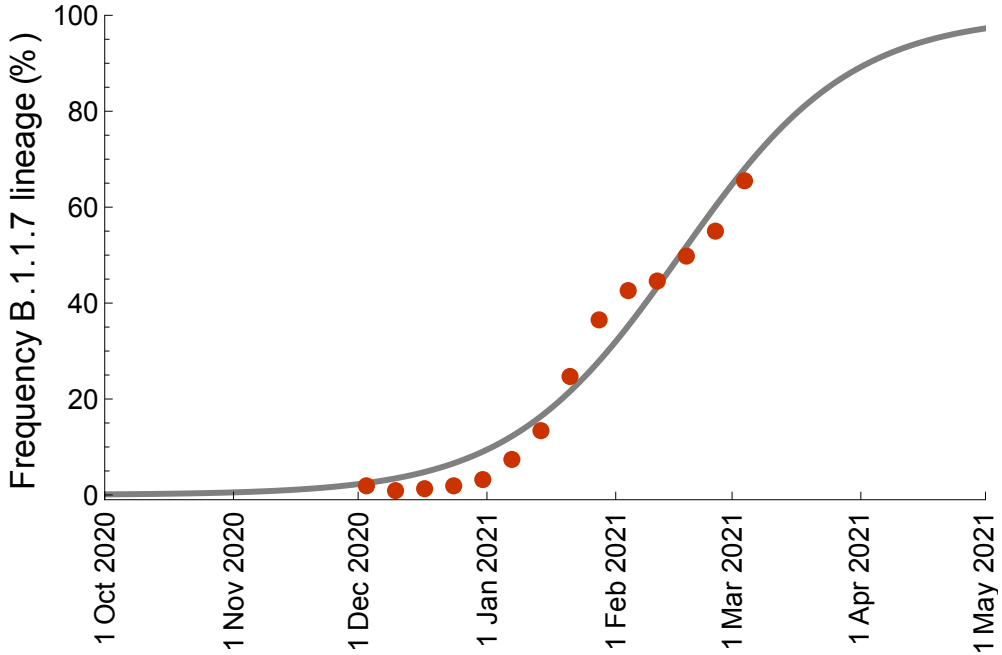
Decreased vaccine efficacy due to antigenic escape variants

+

Pre-pandemic contact rates in the vaccinated population

Main limitations & work in progress

- Hospitalization data ends on 15 January 2021 (start of the third wave)
- No reinfection after natural infection/vaccination (Saad-Roy et al Science 2021; Levine et al Science 2021)
- No seasonality (Kissler et al Science 2021)
- No estimation of selective advantage of B.1.1.7



Conclusion

- Quick relaxation might lead to new waves in 2021
- Substantial measures prove necessary throughout 2021
- More favorable scenarios are relaxation of measures as in summer 2020 or a gradual relaxation until the end of 2021
- Another option would be increasing vaccination rates but this scenario does not seem to be feasible for Portugal

Thank you!