KU LEUVEN

FLANDERS BUSINESS SCHOOL
By KU Leuven


# Scenario-driven forecasting:

## Lessons Learned from Modeling the COVID-19 Pandemic

Men is beginnen forecasten: scenario denken
= populair geworden door 2 grote events in de jaren 70
1. De oliecrisis

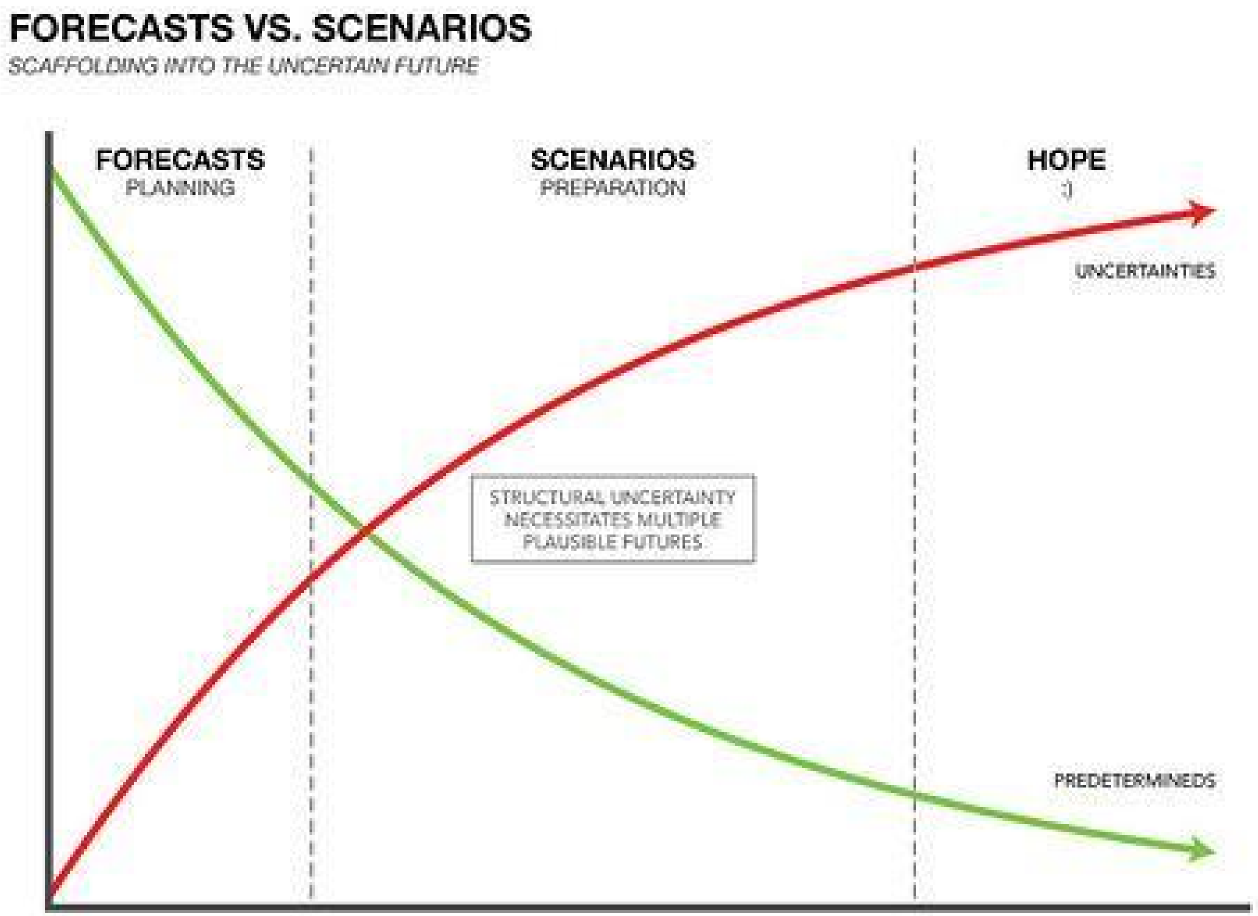
Kristof Decock & prof. dr. Bart Van Looy

# 0. Introduction

# Major differences between foresight and forecasting (Cuhls, 2003)

| Foresight (Scenario Thinking) | Forecasting |
|---|---|
| Basic points, needs, research questions are still open and looked for as part of the foresight process | Basis points, topics and research questions have to be clarified in advance |
| More **qualitative** than quantitative | More **quantitative** than qualitative |
| Looks for '**information**' about the future for priority-setting | Questions what the future in the selected area might look like |
| Brings people together for **discussions** about the future and for networking, makes use of the distributed intelligence | More result-oriented, can also be performed by **individual** people or in single studies (depends on methodology) |
| Criteria for assessment and preparation for **decisions** | Not necessarily assessments, different **options** and choices or the preparation for decisions |
| **Communication** about the future as an objective | Describes future **options**, results more important than the communication aspects |
| Long-, medium- and short-term orientation with implications for today | Long-, medium- and short-term orientation as well as the path into the future are the major points |
| Finds out if there is **consensus** on themes | No information about consensus necessary |
| 'Experts' and other participants, very dependent on **opinions** | Mainly 'expert' and/or strict methodologies, less dependent on opinions |

# Uncertainty rises with time




Hier kom ik bij het ding van daarnet
> x-as: toename onzekerheid. Als het weinig onzeker is kun je goed voorspellen
bv apple: heeft en concreet getal voor ogen hoeveel ze bij de christmas sales gaan verkopen
> Ga je naar meer onzekerheid gaat het moeilijker zijn om kwantitatief juist te zijn

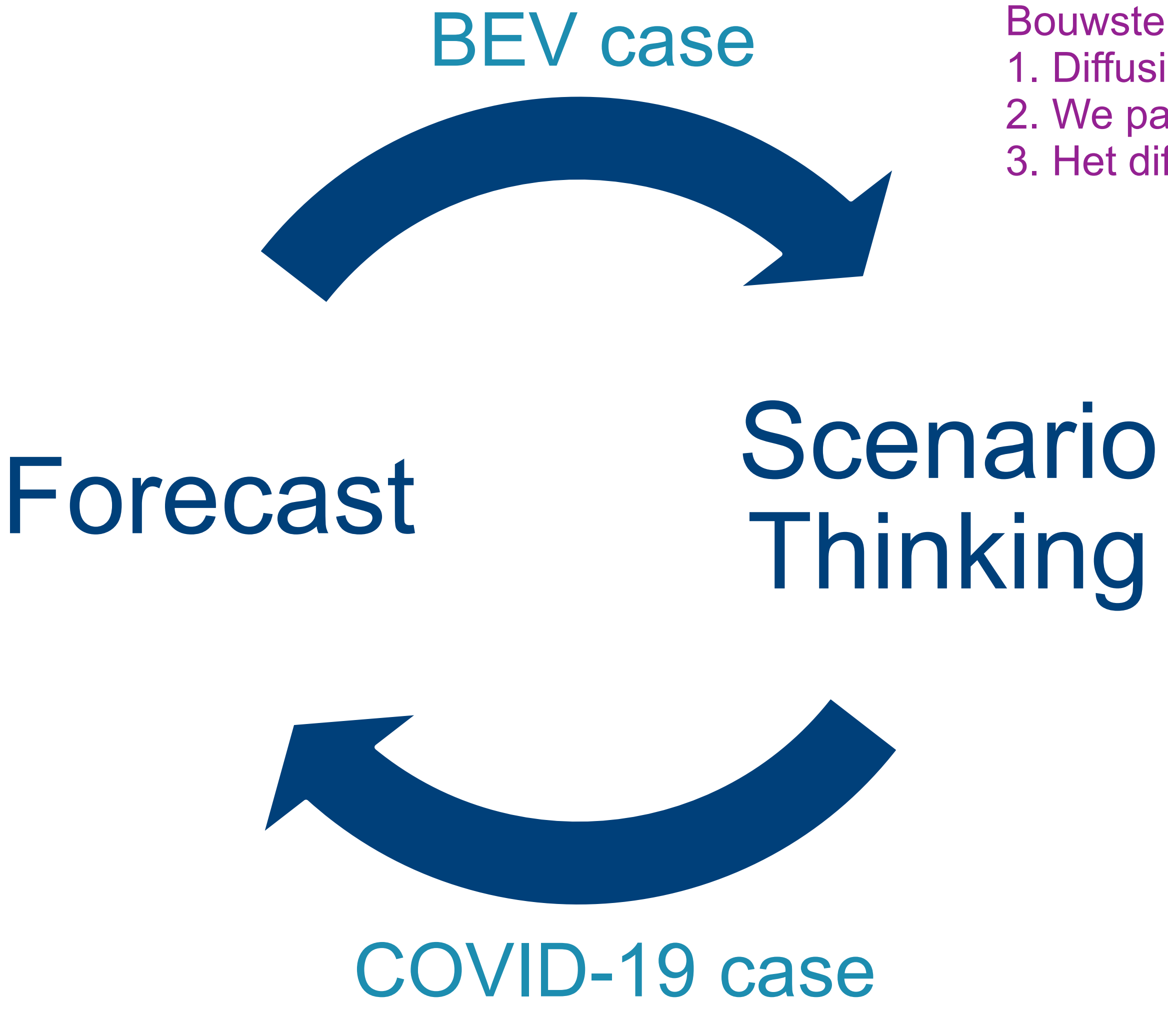
Source: Based on Van der Heijden, K. (1997). Scenarios: The Art of Strategic Conversation.
https://medium.com/larimer/stories-about-the-future-c9e3bf6b1f52

Can (quantitative) forecasting models inform (qualitative) scenario development efforts?

And vice versa?

Literatuur is opgesplitst tussen forecasting en foresighting
> je kunt het niet kwantificeren, je moet het kwalitatief maken. De mensen die beweren dat het wel kunnen zijn arrogante mensen die denken dat de wereld van hun is
> mensen die denken dat ze dat wel kunnen

# Can both disciplines inform each other?




Bouwstenen
1. Diffusie model
2. We passen het toe op innovatie
3. Het diffusiemodel komt van Bass

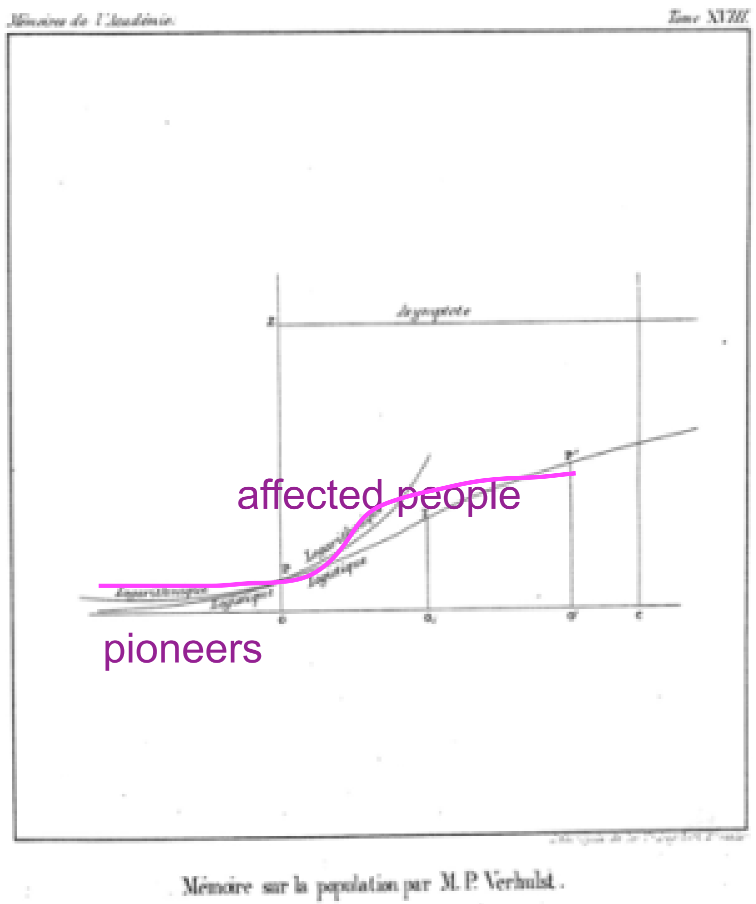
# 1. Diffusion of an innovation: the Bass Model

Als een nieuw product op de markt komt volgt dat een S-curve
> begin = traag: er zijn maar een # mensen geinteresseerd in het product
> zodra de eerste persoon bv met een tesla rond rijd rijden wij eens graag mee (en zijn onder de indruk) > aansteken mensen



# Introduction

- Since the seminal work of Verhulst on population growth, the logistic equation has been introduced by adjusting the exponential growth model with a maximum value for the population (Verhulst, P.-F. (1838). *Note on the law of population growth*).
- Numerous studies in a variety of management disciplines suggest that growth patterns of cumulative sales of new products (over time) result in a S-shape curve (Bass, 1969; Mahajan et. al, 1990; Chandrasekaran & Tellis 2007).
- The logistic function could be used to model life cycles.




*Original image of a logistic curve, contrasted with a logarithmic curve.*
*Source: Verhulst, P.-F. (1845): Recherches mathématiques sur la loi d'accroissement de la population".*

# The Bass Model (Bass, 1969)

Het model beschrijft een S curve

- The Bass model is one of the best-known quantitative models in marketing/innovation studies, describing the diffusion of an innovation (e.g. Mahajan et. al, 1990; Chandrasekaran & Tellis 2007, Massiani & Gohs, 2015)

- The model has been widely adopted by modelers for a number of reasons, e.g., its simplicity and ‘good’ predictive ability (for an overview, see e.g. Parker, 1994; Chandrasekaran & Tellis 2007).

- The Bass model disentangles innovators from imitators regarding the initial adoption of an innovation (e.g. : Bass, 1969; Lekvall and Wahlbin, 1973; Mahajan et al., 1990; Bass, Krishnan, and Jain, 1994).

- Similarity in the underlying growth dynamics to be modelled:
    - Innovation: adoption followed by imitation
    - Epidemics: infection followed by contamination

# The Bass Model (Bass, 1969)

In its discrete form, the Bass model can be written as:

Hoeveel mensen gaan op welk moment in de tijd een electrische outo kopen

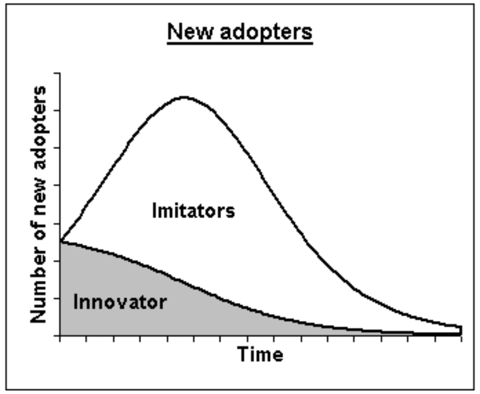
$$N_t = N_{t-1} + p(m - N_{t-1}) + q\frac{N_{t-1}}{m}(m - N_{t-1})$$

Als je zo'n s curve wilt schatten, wanneer wil je die schatten?
> in het aller begin bv e-staps: wordt dat een ding?
- als belegger wil je weten of het een take-off gaat hebben
- dan zijn er heel veel onderzoekers die dit willen weten en die vroeg willen intekenen

Where:

- $N_t$ = the number of adopters at time t (later: ICU occupation or total number of deceased),
- m = the potential market (later: the ultimate number of ICU occupation / deceased),
- p = coefficient of innovation (later: the infection parameter) and,
- q = coefficient of imitation (later: the intensity of contamination),
- $(m – N_{t-1})$ = non-adopters at the beginning of period t,
- $(N_{t-1} / m)$ = the fraction who have already adopted.

In het aller begin: je ziet een # puntjes en dat lijkt omhoog te gaan, maar wat is omhoog gaan?
> dat weet je pas wanneer je in het buigpunt zit (maar dan is het te laat om te investeren)



# Parameter estimation techniques

Waar we gaan eindigen met de electirsche auto, gaan we pas weten zodra we dus aan het buigpunt zitten (waarbij de groei begint te vertragen)

- Notwithstanding sales data for only three observations would be sufficient to theoretically estimate the three parameters p, q and m (as illustrated in Bass, 1969, p. 224), this procedure may be hazardous because of the chaotic nature of early adoption data (Modis & Debecker, 1992).

- Scholars developed several approaches (e.g., OLS, MLE, NLS) to delineate a unique set of parameters (i.e. the one 'optimal' point estimate for m, p, q); however all methods have their limitations, drawbacks and biases and hence are not useful to generate forecasts during the growth phase of the diffusion curve (e.g., Heeler and Hustad, 1980; Schmittlein and Mahajan, 1982; Srinivasan and Mason, 1986; Mahajan et al., 1990; Venkatesan & Kumar, 2002; Chandrasekaran & Tellis, 2007).

- Therefore, Mahajan et. al (1990, p.9) conclude that:

  *" […] parameter estimation for diffusion models is primarily of historical interest; by the time sufficient observations have developed for reliable estimation, it is too late to use the estimates for forecasting purposes."*

# Results

- Thus, ex-ante ‘forecasting’ the diffusion of new products (or novel technologies) by means of quantitative models is problematic for a number of reasons:
  - Diffusion models yield insights retrospectively.
  - Model estimations result in unstable and rudimentary predictions when only few ‘trend’ data are available (i.e. during the early stages of diffusion).
  - Parameter estimations are typically *not* used when the data does only contain pre-takeoff sales (Venkatesan et al., 2004).

- As such, scholars and practitioners alike tend to favor foresight efforts of a more qualitative nature (e.g. scenario development) to project foreseeable futures and their constituents.

# 2. Bass revisited: illustrated with the BEV-case

**Insights from:**
Decock, K., Debackere, K. and Van Looy, B. (2020). Bass Re-visited: Quantifying Multi-Finality. *MSI working paper*, n° 2003.

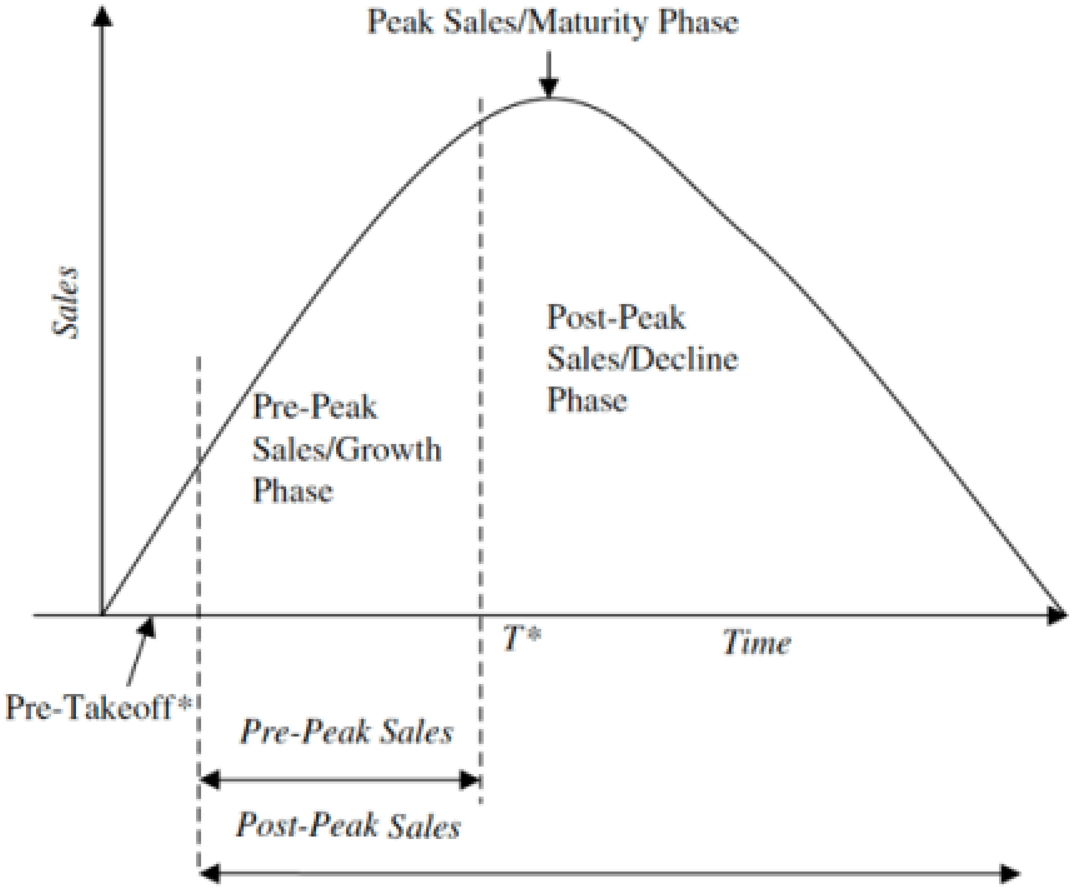
# Research question

Can (quantitative) forecasting models inform (qualitative) scenario development efforts in situations where only relatively short time series are available

(i.e. during the pre-takeoff phase)?

Helpt het nu bij het nemen van beslissingen in hoge onzekere situaries?

**Figure 1 Sample Diffusion Path of a New Product Innovation**




*Typically not used in diffusion model estimation.

Source: Venkatesan, R., Krishnan, T. and Kumar, V. (2004)

# Novel Heuristics connecting Scenario Thinking with Forecasting Logics (and assuming multi-finality)

- Starting from the Bass model, we develop an exhaustive, three-dimensional search space to assess a wide range of values for each parameter looking for local optima instead of one global optimum. (Scenario Thinking)

- The grid consists of 500.000 scenarios for each region (EU and US), i.e. 10 (m) x 250 (p) x 200 (q), with ranges consistent with parameters from literature:
  - 10% ≤ m ≤ 100%
  - 0,00001 ≤ p ≤ 0,00250
  - 0,01 ≤ q ≤ 2,00

We gaan niet meer op zoek naar de S, maar gaan er vanuit dat het alle kanten kan uitgaan (the principle of miltifinality), we stellen ons dus open voor een veelheid aan scenario's

- A loss function is defined, based on the fit with actual diffusion patterns; the goodness-of-fit for each scenario is calculated as $R^2 = 1 - \frac{SS\ Error}{SS\ Observed}$

- Models with an $R^2 > 0,99$ were retrieved and labelled as the "*more likely* scenarios", i.e. are best in explaining what we currently already observe in terms of market adoption (Connecting with Forecasting).

# Multi-Finality

- Buckley (1967): “Similar initial conditions may lead to dis-similar end-states” (Sociology and Modern System Theory, Prentice Hall).

- *Multifinality* holds that similar initial conditions may lead to dissimilar outcomes (Feiring & Lewis, 1987).

# Data: Key figures about European and U.S. fleet

| | Europe | United States |
|---|---|---|
| Number of cars (2016, mio) | 259,7 | 113 |
| New annual registrations (2016, mio) | 15 | 6,3 |
| Average age | 11 | 11,6 |
| Renewal period (in years) | 17 | 18 |
| Market share (2017) of BEV | 0,12% | 0,35% |

(Sources: European Automobile Manufacturers Association & European Environment Agency; statista.com)

# Data: Cumulative sales data on BEV in Europe and U.S.

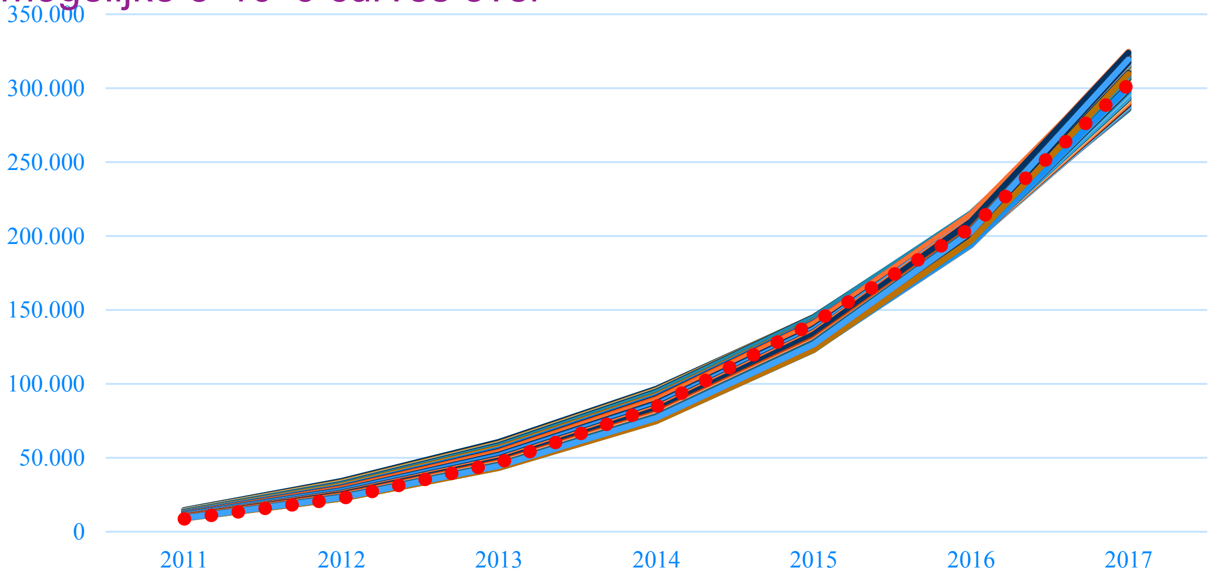
Er waren dus maar 7 datapunten
> begin in 2011: door oprichting Tesla

| Year | Stock BEV in Europe | Stock BEV in U.S. |
|---|---|---|
| 2011 | 8.493 | 10.060 |
| 2012 | 22.479 | 24.710 |
| 2013 | 46.654 | 72.404 |
| 2014 | 84.509 | 135.820 |
| 2015 | 141.265 | 206.864 |
| 2016 | 205.581 | 293.595 |
| 2017 | 302.724 | 398.066 |

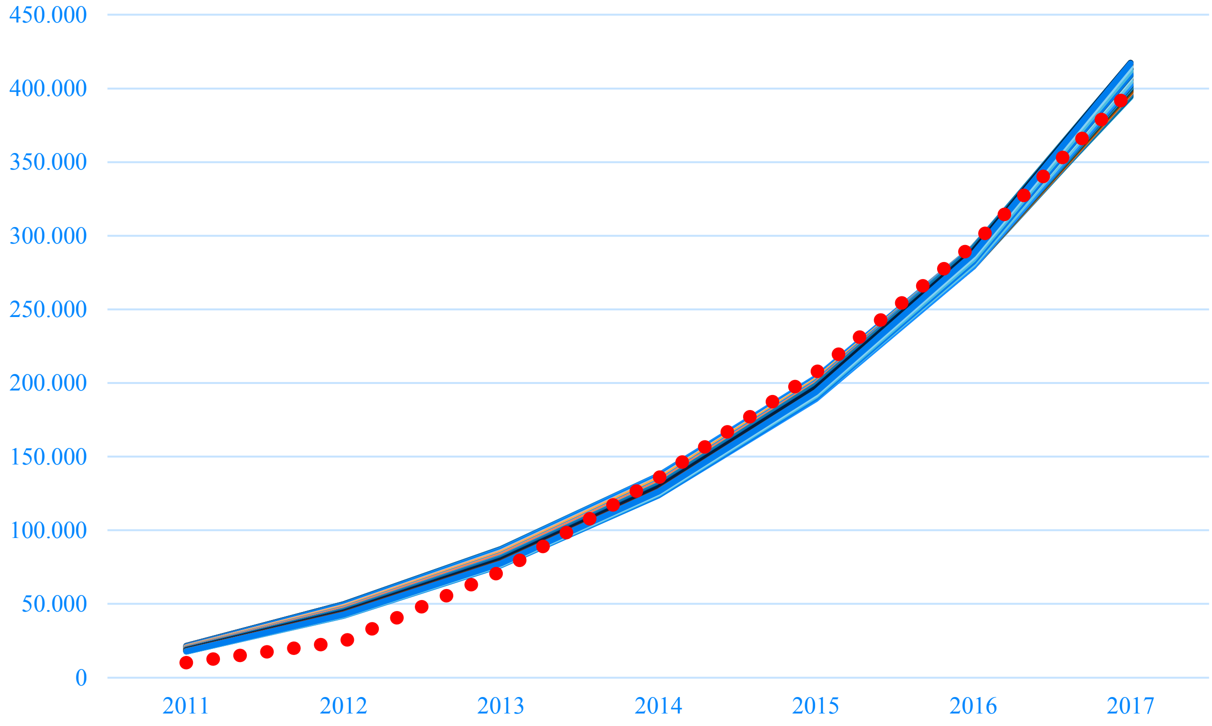
(Sources: European Environment Agency; U.S. Department of Energy – Energy Efficiency and Renewable Energy, hybridcars.com)

# Goodness-of-fit of the *more likely* scenarios ($R^2$ > ,9965) in Europe (left) and U.S. (right)

Hiermee bereken je heel veel curves
> je gaat alleen die curves bekijken die voor 90 of 99% fitten met wat we zeker weten
> goede nieuws: er bijven nog maar 150 van alle berekende mogelijke 5*10^6 curves over



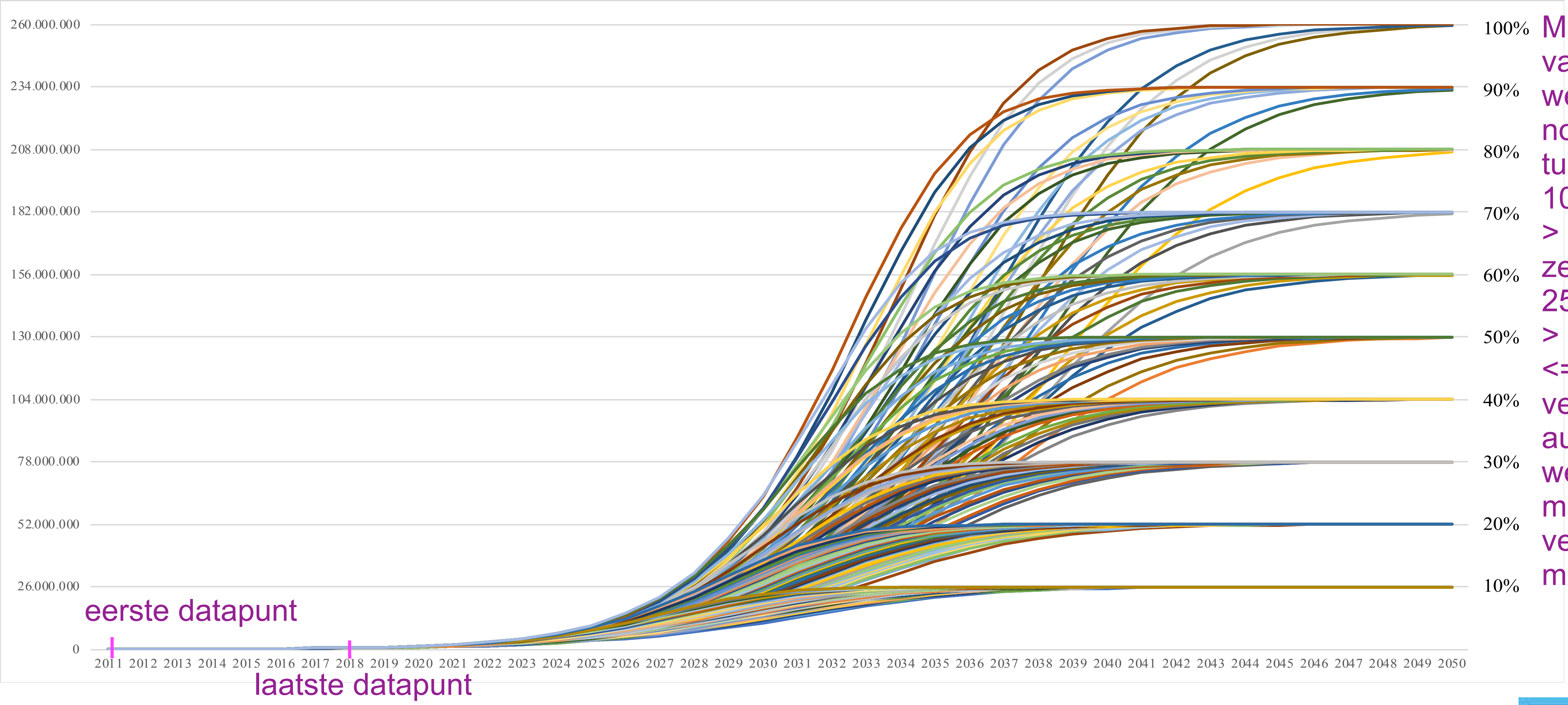

*(n = 211)*




*(n = 148)*

# More likely scenarios (R² > ,9965) for Battery EV in Europe (n = 211)

Als je de 200 curves dan bekijkt dan krijg je




Met het zetten van de filter zien we dat we nogsteeds tussen de 10 en 100% zaten
> prof: in 2025 zegt de krant der 25% electrisch is
> ik zeg 2.5%
<=>
verschillende autofabrikanten: we gaan stoppen met verbrandings-motoren

Als we hetzelfde voen voor BEV voor BE als met covid:

# Descriptive Statistics BEV in Europe, incl. 2010 ($R^2$ > ,99; n= 321)

| | Market Share | | | New BEV entrants | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Min | Max | Average | Min | % | Max | % | Average | % |
| 2018 | 0,15% | 0,21% | 0,18% | 108.093,90 | 0,72% | 215.541,19 | 1,44% | **152.699,95** | 1,02% |
| 2019 | 0,21% | 0,35% | 0,26% | 145.416,81 | 0,97% | 351.241,89 | 2,34% | 226.631,29 | 1,51% |
| 2020 | 0,28% | 0,56% | 0,39% | 195.378,54 | 1,30% | 577.036,93 | 3,85% | 336.297,46 | 2,24% |
| 2021 | 0,38% | 0,93% | 0,58% | 262.057,74 | 1,75% | 945.305,52 | 6,30% | 498.177,50 | 3,32% |
| 2022 | 0,52% | 1,52% | 0,87% | 348.128,24 | 2,32% | 1.541.410,04 | 10,28% | 734.992,48 | 4,90% |
| 2023 | 0,70% | 2,48% | 1,28% | 458.779,77 | 3,06% | 2.494.249,59 | 16,63% | 1.076.210,61 | 7,17% |
| 2024 | 0,93% | 4,01% | 1,88% | 599.618,20 | 4,00% | 3.985.767,67 | 26,57% | 1.556.098,14 | 10,37% |
| 2025 | 1,23% | 6,41% | 2,73% | 775.148,73 | 5,17% | 6.240.048,53 | 41,60% | 2.206.728,15 | 14,71% |
| 2030 | 4,13% | 44,72% | 12,62% | 693.547,67 | 4,62% | 32.323.147,47 | 215,49% | 7.211.956,36 | 48,08% |
| 2035 | 8,14% | 94,54% | 26,63% | 4.290,21 | 0,03% | 29.145.225,56 | 194,30% | 5.979.862,00 | 39,87% |
| 2040 | 9,72% | 99,92% | 32,79% | 22,51 | 0,00% | 20.369.162,15 | 135,79% | 1.667.145,40 | 11,11% |
| 2045 | 9,97% | 100,00% | 33,95% | 0,12 | 0,00% | 6.580.460,67 | 43,87% | 210.859,55 | 1,41% |

*New BEV entrants, Actuals 2018: 150.003*

# Market share distribution of the *more likely* scenarios (i.e. $R^2$ > ,99)

| Market share | Europe Count | Europe % | United States Count | United States % |
|---|---|---|---|---|
| 10% | 234 | 34% | 646 | 35% |
| 20% | 117 | 17% | 320 | 17% |
| 30% | 79 | 11% | 211 | 11% |
| 40% | 58 | 8% | 157 | 8% |
| 50% | 47 | 7% | 128 | 7% |
| 60% | 40 | 6% | 104 | 6% |
| 70% | 34 | 5% | 91 | 5% |
| 80% | 29 | 4% | 78 | 4% |
| 90% | 27 | 4% | 67 | 4% |
| 100% | 24 | 3% | 62 | 3% |
| Total | 689 | 100% | 1.864 | 100% |

| Parameter | Europe Min | Europe Max | United States Min | United States Max |
|---|---|---|---|---|
| p value | 0,00003 | 0,00067 | 0,00012 | 0,00241 |
| q value | 0,28 | 0,62 | 0,23 | 0,51 |

# Conclusions

- Rather than searching for the ultimate set of parameter estimates, the proposed heuristics focus on revealing a set of potential outcomes, building on relatively short time series (before growth phase).

- The heuristics implied allow to assess and quantify the multi-finality of novel trajectories, enabling to consider multiple pathways towards local optima, ex-ante and simultaneously.

- It becomes feasible to assess the likelihood as well as time horizon of different scenarios, and thus offers the potential to assess and model uncertainty (Knight, 1920) in a quantitative manner; however, not in a deterministic way.

- The presence of multiple trajectories towards the future, directs our attention to consider explicitly the antecedents required for different scenarios to unfold.

- As such, forecasting becomes a valuable, informative complement of scenario development exercises rather than an inferior or even neglected substitute.

# From BEV towards COVID-19

**Nederlandse onderzoekers voorspellen evolutie corona met modellen uit 1845 van Belgische wiskundige**

Door modellen voor de groei van populaties los te laten op wereldwijde coronadata zijn Eindhovense datawetenschappers in staat om het te verwachten aantal nieuwe besmettingen en doden als gevolg van het SARS-CoV-2 virus te berekenen voor de nabije toekomst. Voor zeven landen – China, Zuid-Korea, Iran, Italië, Frankrijk, de VS en Nederland – is een nauwkeurige voorspelling mogelijk van één tot drie dagen vooruit. Voor sommige landen kunnen ze ook een schatting maken van het maximum aantal bevestigde infecties.

Luc De Roy
ma 16 mrt 19:41

- Epidemiological models (e.g. Bayesian SEIR modeling) require knowledge on the underlying epidemiological parameters to yield accurate predictions. These parameters are unknown during the early phases of the emerging virus (i.e. before the inflection points).

- To what extent could diffusion models - widely known and used within the innovation (and technology) discipline - bear relevance for modeling and forecasting pandemic phenomena like the COVID-19 virus :
  - Innovation followed by imitation
  - Infection followed by contamination

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# Modeling the COVID-19 Pandemic

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# 3. Italian case

**Insights from:**

Decock, K., Bergamini, M., Debackere, K., Lupi, E., Vandamme A.-M. and Van Looy, B. (2020). Predicting when peaks will occur, ex ante: Insights from the COVID-19 Pandemic in Italy and Belgium. *Under review*

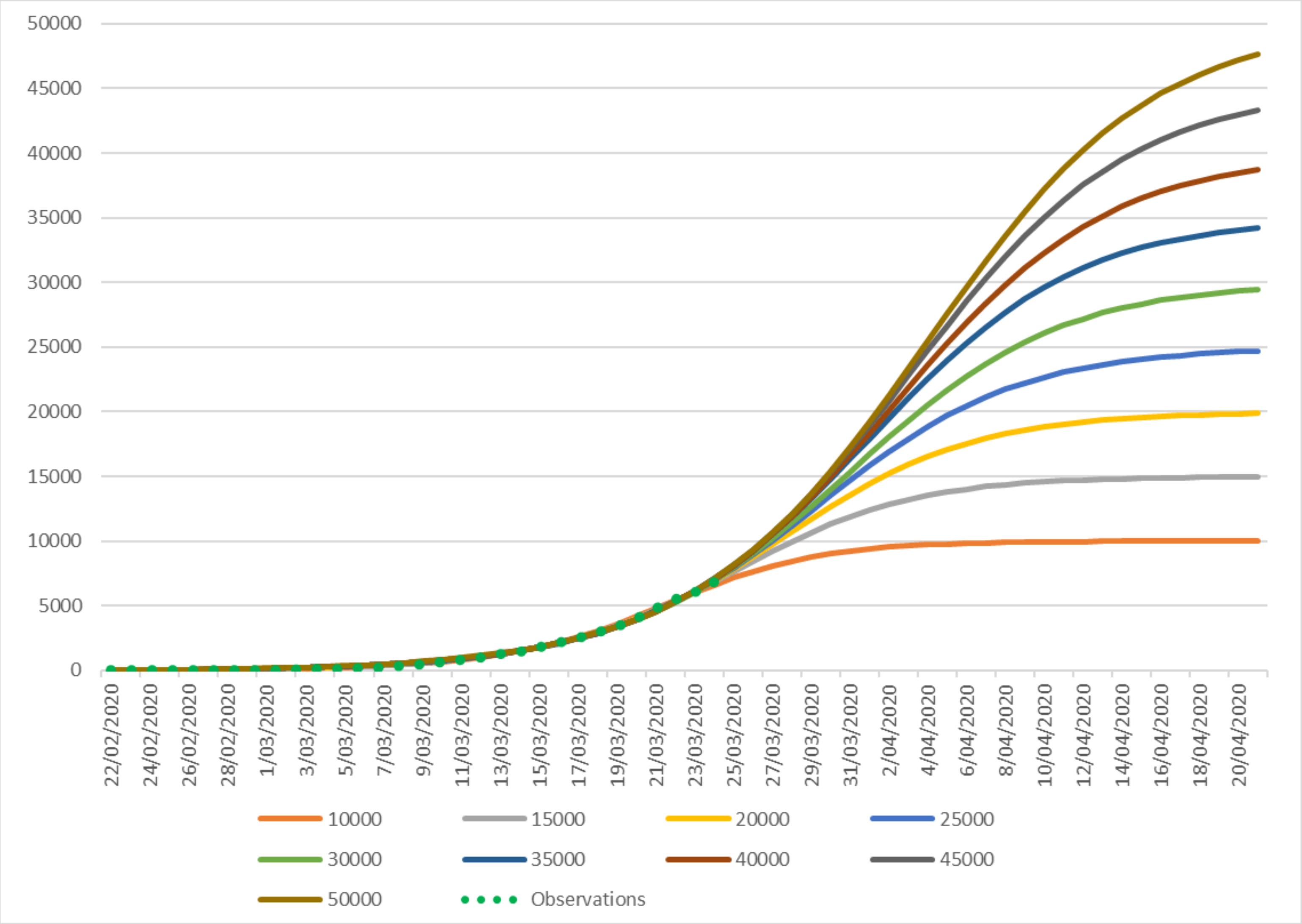
# Introduction

- On Friday 20/03, we started apply the heuristics developed to model the diffusion of the Electrical Car (Decock, Debackere & Van Looy, 2020) towards the COVID-19 pandemic.
- We focused our efforts on deceased on the one hand, and ICU occupation levels on the other hand.
- In this PPT, we report major findings for Italy, pertaining to the number of cumulative deceased.
- We report models with different levels of granulation (in terms of end states) as this allows to assess the consistencies of the patterns emerging.
- Source data: www.protezionecivile.gov.it

# First round of models

- The reported COVID-19 deceased for Italy exceeded 10 on 25/02.
- We created first models for Italy, on 25/03, based on data starting from 22/02, running till 24/03 (32 days).
- End-states ranged from 10 to 50.000 (cumulative deceased) with steps of 5.000.
- The heuristics at that moment no longer include an end state totaling 5.000 cumulative deceased.
- As the following graph shows, 9 different end states (ranging between 10.000 & 50.000) are at that moment plausible.

| Date | N. deceased (cumulative) |
|---|---|
| 22/02/2020 | 2 |
| 23/02/2020 | 2 |
| 24/02/2020 | 6 |
| 25/02/2020 | 11 |
| 26/02/2020 | 12 |
| 27/02/2020 | 17 |
| 28/02/2020 | 21 |
| 29/02/2020 | 29 |
| 1/03/2020 | 35 |
| 2/03/2020 | 52 |
| 3/03/2020 | 80 |
| 4/03/2020 | 107 |
| 5/03/2020 | 148 |
| 6/03/2020 | 197 |
| 7/03/2020 | 233 |
| 8/03/2020 | 366 |
| 9/03/2020 | 464 |
| 10/03/2020 | 631 |
| 11/03/2020 | 827 |
| 12/03/2020 | 1016 |
| 13/03/2020 | 1268 |
| 14/03/2020 | 1441 |
| 15/03/2020 | 1811 |
| 16/03/2020 | 2158 |
| 17/03/2020 | 2505 |
| 18/03/2020 | 2978 |
| 19/03/2020 | 3407 |
| 20/03/2020 | 4032 |
| 21/03/2020 | 4825 |
| 22/03/2020 | 5476 |
| 23/03/2020 | 6072 |
| 24/03/2020 | 6820 |
| 25/03/2020 | 7503 |
| 26/03/2020 | 8165 |
| 27/03/2020 | 9134 |
| 28/03/2020 | 10023 |
| 29/03/2020 | 10779 |
| 30/03/2020 | 11591 |
| 31/03/2020 | 12428 |
| 1/04/2020 | 13155 |
| 2/04/2020 | 13915 |
| 3/04/2020 | 14681 |
| 4/04/2020 | 15362 |
| 5/04/2020 | 15887 |
| 6/04/2020 | 16523 |

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# First round of models

- When one adds to this graph the reported numbers for the time period 25/03 till 06/04 (red dots – figure on the next slide), it seems that Italy is walking a line towards an end-state situated between 10.000 & 20.000 deceased, with actual levels much closer to the 20.000 curve than the 10.000.

- According to these graphs, the peak for the 10 K curve would imply 619 deceased on 21/03; the peak for the 20 K curve would imply 984 deceased on 28/03.

- The peak for Italy (so far) was Friday 27/03 with 969 reported deceased.

- On that evening, we reached out to Sant'Anna to signal our work and to indicate that our models suggested a peak soon (based on the 18K-19K deceased scenarios, which signaled peak levels on Friday 27/03 and the weekend ).

Da: Bart Van Looy <bart.vanlooy@kuleuven.be>

Data: 27/03/20 19:09 (GMT+01:00)

A: Arianna Menciassi <arianna.menciassi@santannapisa.it>, sabina.nuti@santannapisa.it

Cc: Andrea Piccaluga <andrea.piccaluga@santannapisa.it>, alberto.diminin@santannapisa.it

Oggetto: Italy COV19

Hello Sabina, Arianna,

I’m reaching out related to the COV19 situation.
Since one week, we (Kristof, I and a small team) are modelling the diffusion (deceased & ICU) of COV19 for BE, NL, IT, ES, FR,…based on diffusion models we develop in the framework of the PhD of Kristof Decock and which also have been applied as part of the EIB project.
We (including Koen Debackere who is following the process closely) are currently convinced that our approach does a better job than wat is available/used.

We are already advising/informing the Belgian authorities on capacity planning etc.
As for Italy, we also have estimates on how things will evolve during the next 10 days. I would like to discuss these estimates so you can assess whether this could be useful/hopeful for Italy.
I’m now going out for a run, but could skype this evening, around 21.00 or so. If someone else at Sant’Anna would be better placed to have a look at this, let me know.
Best wishes,

Talk soon,

Bart

**From:** sabina.nuti <sabina.nuti@santannapisa.it>
**Sent:** vrijdag 27 maart 2020 22:41
**To:** Bart Van Looy <bart.vanlooy@kuleuven.be>; Arianna Menciassi <arianna.menciassi@santannapisa.it>
**Cc:** Andrea Piccaluga <andrea.piccaluga@santannapisa.it>; alberto.diminin@santannapisa.it
**Subject:** RE: Italy COV19

Dear Bart, we have a large group of researchers working on this issue . The Italian contest has large differences among the italian regions that have to be considered. We are working with our government and we will ve happy to collaborare with you. Best Sabina

Inviato da smartphone Samsung Galaxy.

**From:** Bart Van Looy
**Sent:** zaterdag 28 maart 2020 2:32
**To:** 'sabina.nuti' <sabina.nuti@santannapisa.it>; Arianna Menciassi <arianna.menciassi@santannapisa.it>
**Cc:** Andrea Piccaluga <andrea.piccaluga@santannapisa.it>; alberto.diminin@santannapisa.it; Kristof Decock <kristof.decock@kuleuven.be>
**Subject:** RE: Italy COV19

Hello Sabina, all,

Please find included the xls in which we model Italy. Only deceased.

We examine several scenarios of diffusion (250.000) and then select the most plausible ones.
This approach – for the details see paper in attach – yielded a prediction for the reported casualties on 27.03 of 931 while the actual number was 919. We have the same level of accuracy for Spain, Belgium,…

We started to develop/apply the models 8 days ago and the results for Italy have been consistent/accurate for 7 days in a row now. If you extend this forecast, Italy will have similar numbers today (Saturday) and tomorrow, and then the decline will set in

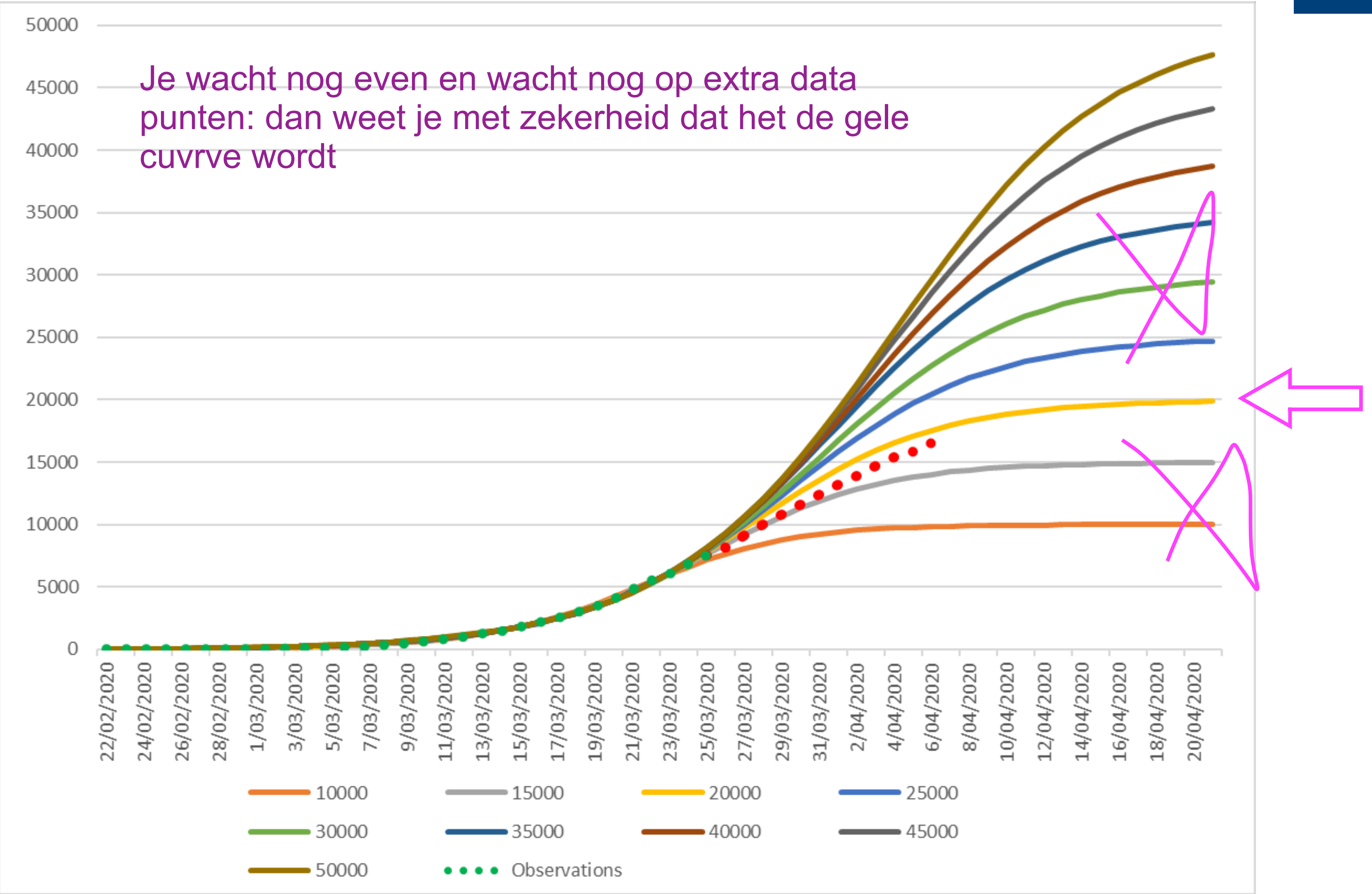
The end state which we predict for Italy will be around 18.000 casualties. While this might sound as a lot and still 9.000 to go, we also think that it is important to signal that after a very heavy weekend (with again casualties around 900 for Saturday and Sunday), it will become better from next week onwards (Monday).

Let me/us know if this is useful and if this can be helpful to cope with the current situation in Italy.

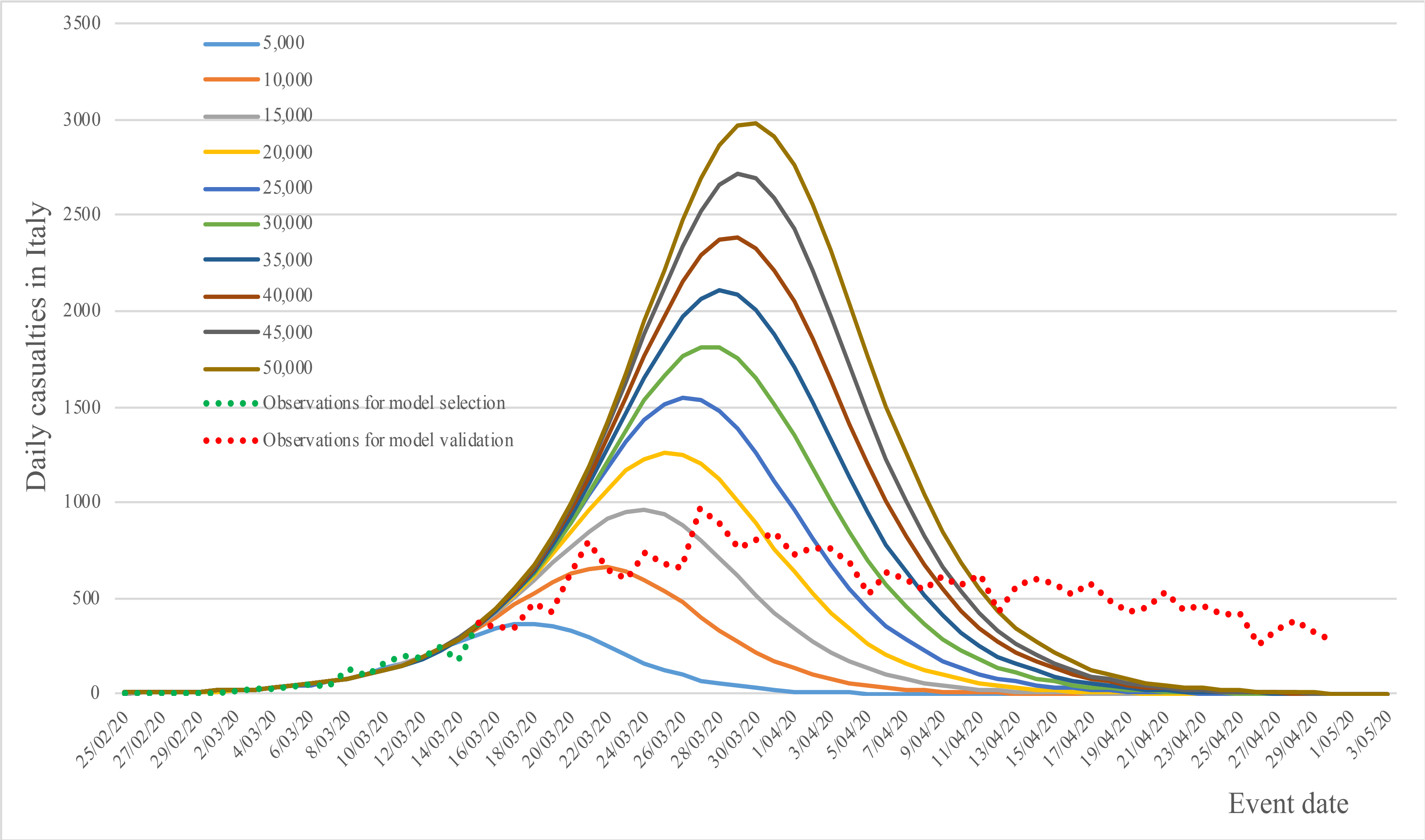
Similar models for Belgium are now being used here to 'manage' the situation, including the ICU capacity.
We can call tomorrow around lunch time, i.e. after we have incorporated the most recent data for BE in our forecasts (the numbers are released around 11.00).
Take care, talk soon,

Bart

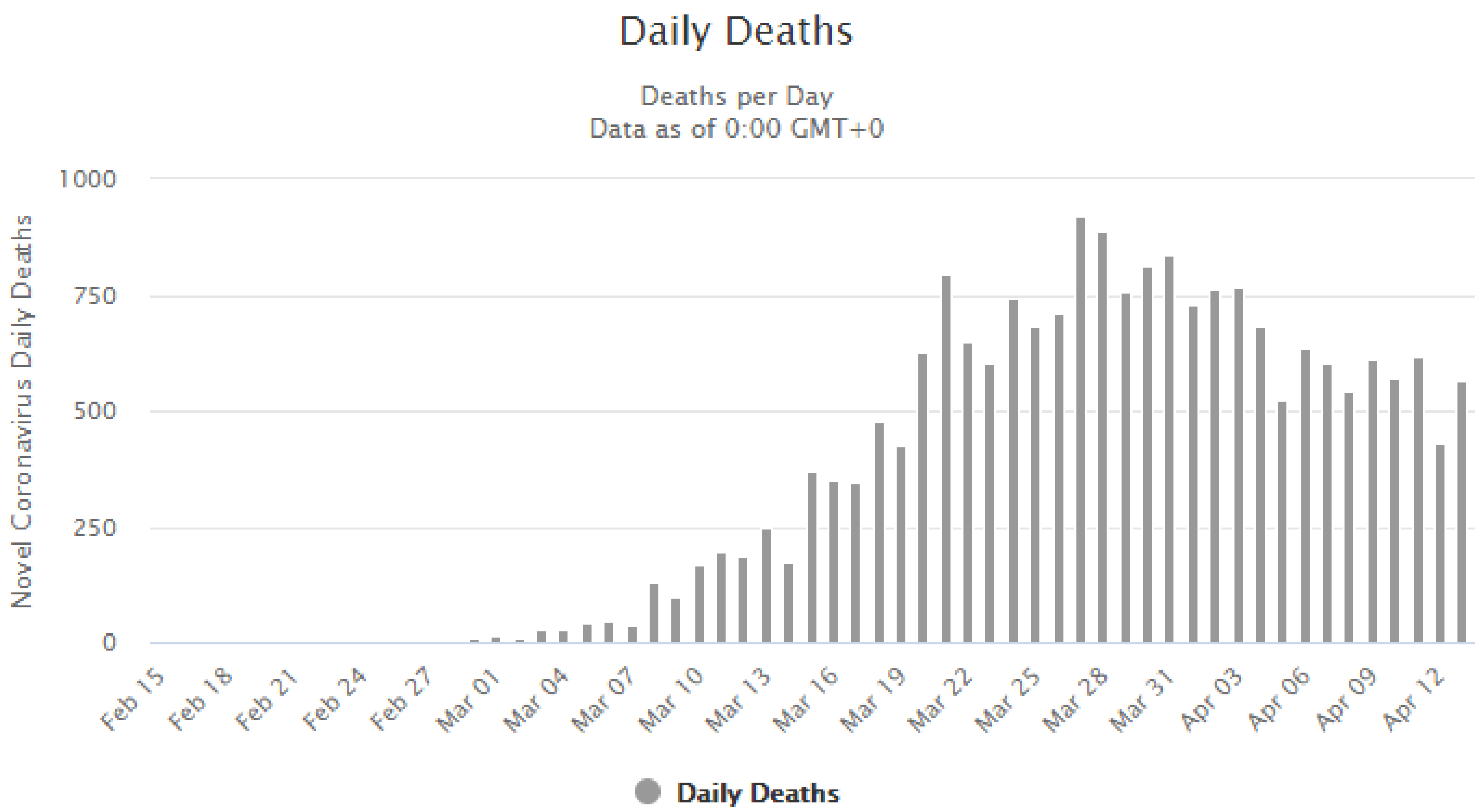
| Date | N. deceased (cumulative) |
|---|---|
| 22/02/2020 | 2 |
| 23/02/2020 | 2 |
| 24/02/2020 | 6 |
| 25/02/2020 | 11 |
| 26/02/2020 | 12 |
| 27/02/2020 | 17 |
| 28/02/2020 | 21 |
| 29/02/2020 | 29 |
| 1/03/2020 | 35 |
| 2/03/2020 | 52 |
| 3/03/2020 | 80 |
| 4/03/2020 | 107 |
| 5/03/2020 | 148 |
| 6/03/2020 | 197 |
| 7/03/2020 | 233 |
| 8/03/2020 | 366 |
| 9/03/2020 | 464 |
| 10/03/2020 | 631 |
| 11/03/2020 | 827 |
| 12/03/2020 | 1016 |
| 13/03/2020 | 1268 |
| 14/03/2020 | 1441 |
| 15/03/2020 | 1811 |
| 16/03/2020 | 2158 |
| 17/03/2020 | 2505 |
| 18/03/2020 | 2978 |
| 19/03/2020 | 3407 |
| 20/03/2020 | 4032 |
| 21/03/2020 | 4825 |
| 22/03/2020 | 5476 |
| 23/03/2020 | 6072 |
| 24/03/2020 | 6820 |
| 25/03/2020 | 7503 |
| 26/03/2020 | 8165 |
| 27/03/2020 | 9134 |
| 28/03/2020 | 10023 |
| 29/03/2020 | 10779 |
| 30/03/2020 | 11591 |
| 31/03/2020 | 12428 |
| 1/04/2020 | 13155 |
| 2/04/2020 | 13915 |
| 3/04/2020 | 14681 |
| 4/04/2020 | 15362 |
| 5/04/2020 | 15887 |
| 6/04/2020 | 16523 |



# Italy as a whole, model selection based on 24/2-15/3



# Daily New Deaths in Italy

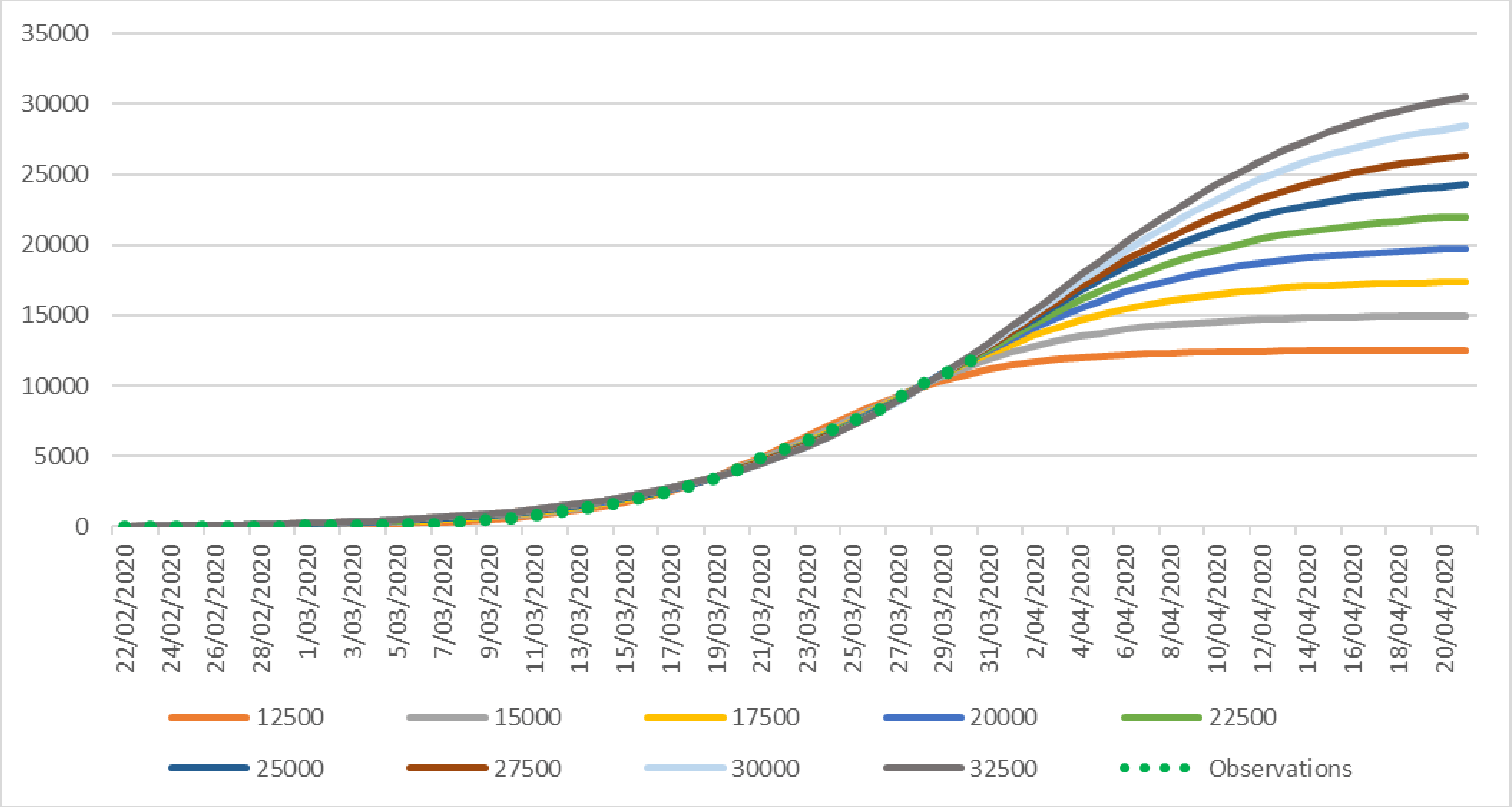



https://www.worldometers.info/coronavirus/country/italy/

# Second round of models

- We updated the models by including data until 31/03.
- In total, the number of days used for calculating the models and selecting the more plausible ones, amounts now to 39 days.
- End-states ranged from 10.000 to 32.500 (cumulative deceased) with steps of 2.500.
- The heuristics at that moment no longer include end-state totaling 10.000 cumulative deceased.
- As the following graph shows, 9 different end-states (ranging 12.500 to 32.500) are at that moment plausible.

| Date | N. deceased (cumulative) |
|---|---|
| 22/02/2020 | 2 |
| 23/02/2020 | 2 |
| 24/02/2020 | 6 |
| 25/02/2020 | 11 |
| 26/02/2020 | 12 |
| 27/02/2020 | 17 |
| 28/02/2020 | 21 |
| 29/02/2020 | 29 |
| 1/03/2020 | 35 |
| 2/03/2020 | 52 |
| 3/03/2020 | 80 |
| 4/03/2020 | 107 |
| 5/03/2020 | 148 |
| 6/03/2020 | 197 |
| 7/03/2020 | 233 |
| 8/03/2020 | 366 |
| 9/03/2020 | 464 |
| 10/03/2020 | 631 |
| 11/03/2020 | 827 |
| 12/03/2020 | 1016 |
| 13/03/2020 | 1268 |
| 14/03/2020 | 1441 |
| 15/03/2020 | 1811 |
| 16/03/2020 | 2158 |
| 17/03/2020 | 2505 |
| 18/03/2020 | 2978 |
| 19/03/2020 | 3407 |
| 20/03/2020 | 4032 |
| 21/03/2020 | 4825 |
| 22/03/2020 | 5476 |
| 23/03/2020 | 6072 |
| 24/03/2020 | 6820 |
| 25/03/2020 | 7503 |
| 26/03/2020 | 8165 |
| 27/03/2020 | 9134 |
| 28/03/2020 | 10023 |
| 29/03/2020 | 10779 |
| 30/03/2020 | 11591 |
| 31/03/2020 | 12428 |
| 1/04/2020 | 13155 |
| 2/04/2020 | 13915 |
| 3/04/2020 | 14681 |
| 4/04/2020 | 15362 |
| 5/04/2020 | 15887 |
| 6/04/2020 | 16523 |



# Second round of models

- When one adds to this graph the reported numbers for the time period till 06/04 (red dots), it seems that Italy is walking a line towards an end-state situated between 18.000 and 20.000 deceased, with actual levels closer to the 20.000 curve than the 18.000.

- This range is in line with the observed patterns and their implications which build on data till 24/03

- Given the peak levels reported before, this update confirms that decline of the curve is manifesting itself in a consistent manner.

- The final graph on the next slide depicts the predictions derived from different end-states together with the actual observations on a *daily* base.

| Date | N. deceased (cumulative) |
|---|---|
| 22/02/2020 | 2 |
| 23/02/2020 | 2 |
| 24/02/2020 | 6 |
| 25/02/2020 | 11 |
| 26/02/2020 | 12 |
| 27/02/2020 | 17 |
| 28/02/2020 | 21 |
| 29/02/2020 | 29 |
| 1/03/2020 | 35 |
| 2/03/2020 | 52 |
| 3/03/2020 | 80 |
| 4/03/2020 | 107 |
| 5/03/2020 | 148 |
| 6/03/2020 | 197 |
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| 24/03/2020 | 6820 |
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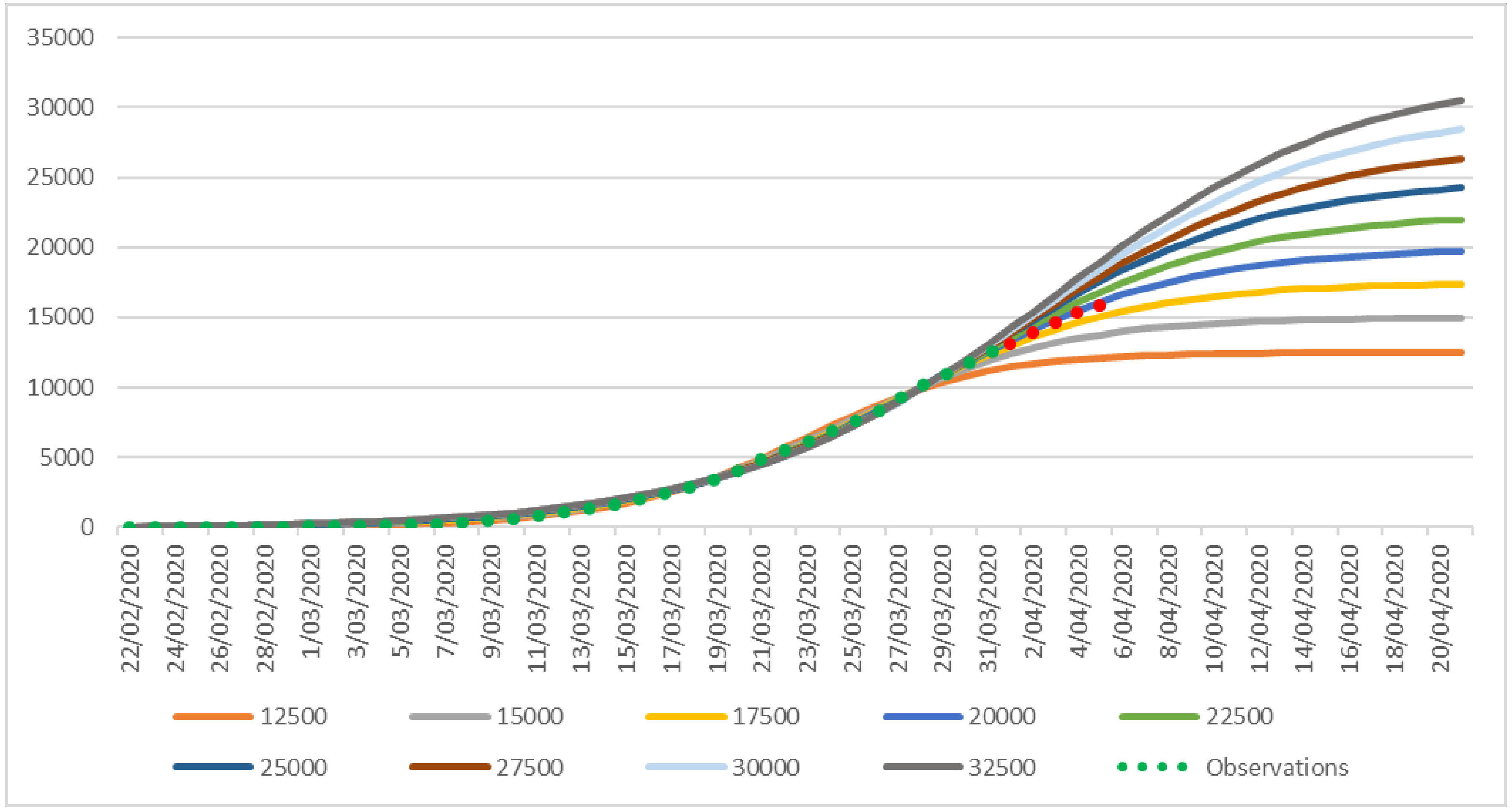
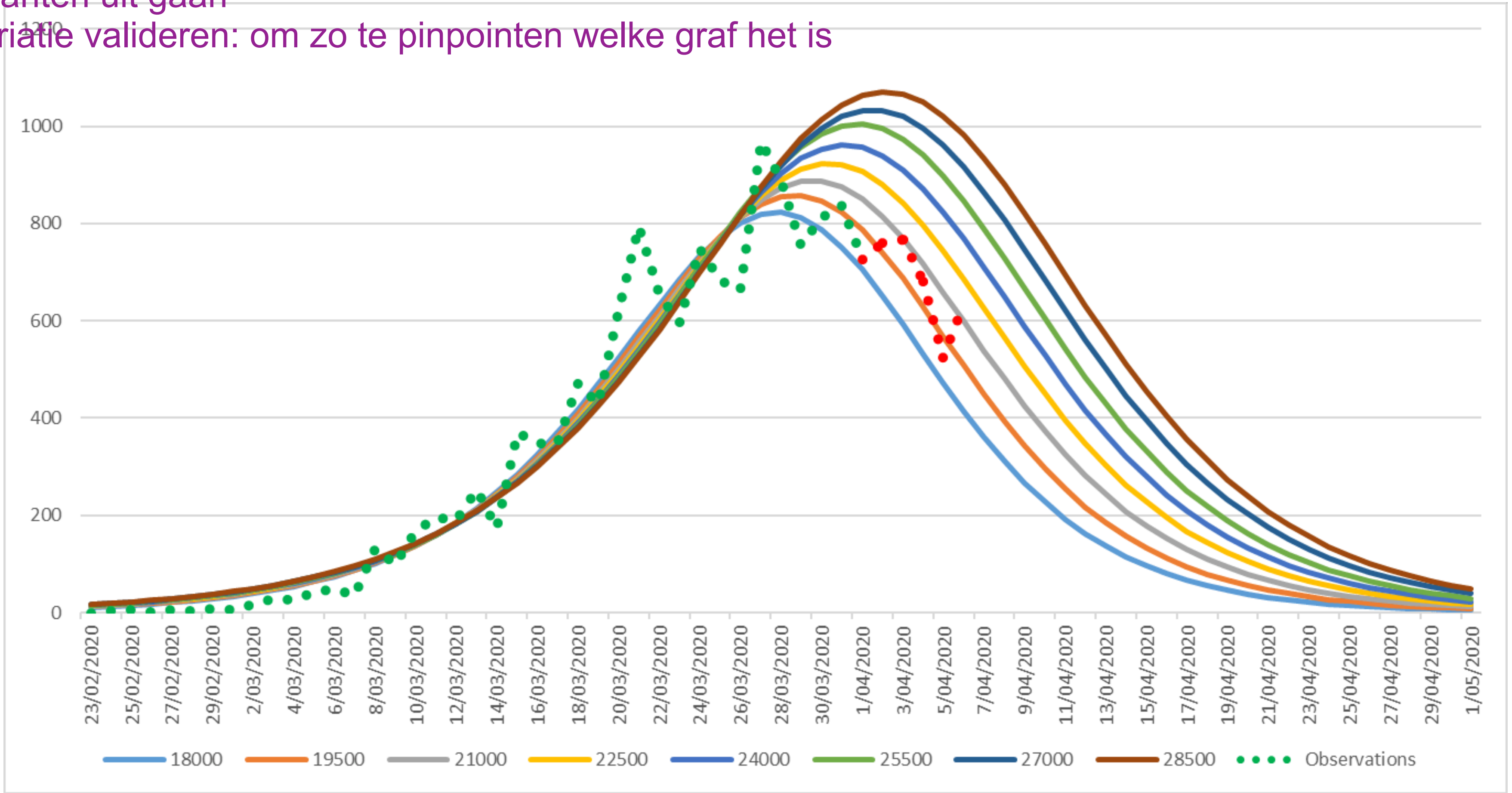
| 26/03/2020 | 8165 |
| 27/03/2020 | 9134 |
| 28/03/2020 | 10023 |
| 29/03/2020 | 10779 |
| 30/03/2020 | 11591 |
| 31/03/2020 | 12428 |
| 1/04/2020 | 13155 |
| 2/04/2020 | 13915 |
| 3/04/2020 | 14681 |
| 4/04/2020 | 15362 |
| 5/04/2020 | 15887 |
| 6/04/2020 | 16523 |



# Italy – Update 07/04

Je gaat naar de toekosmt denken vanuit scenario logica
> het kan alle kanten uit gaan
> en dan de variatie valideren: om zo te pinpointen welke graf het is

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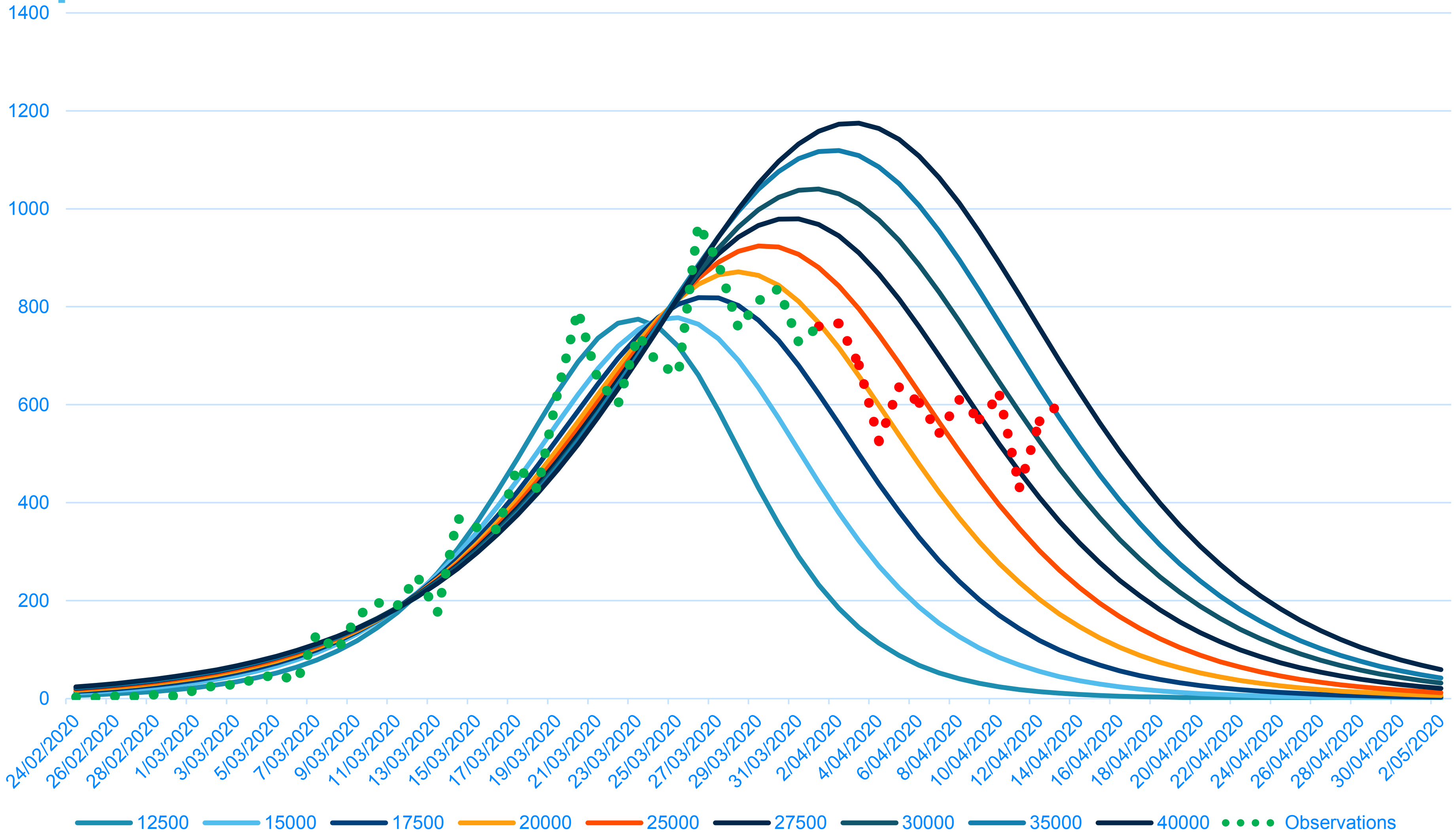
# Italy Update 14/04

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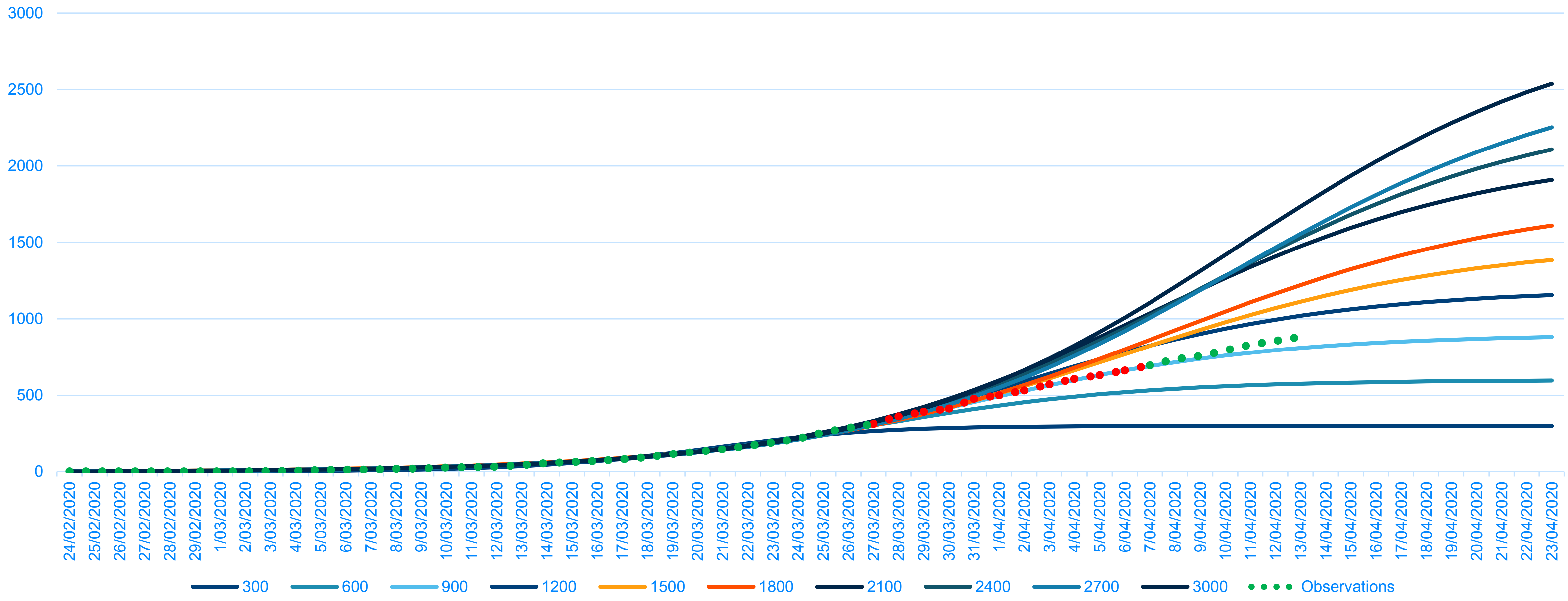
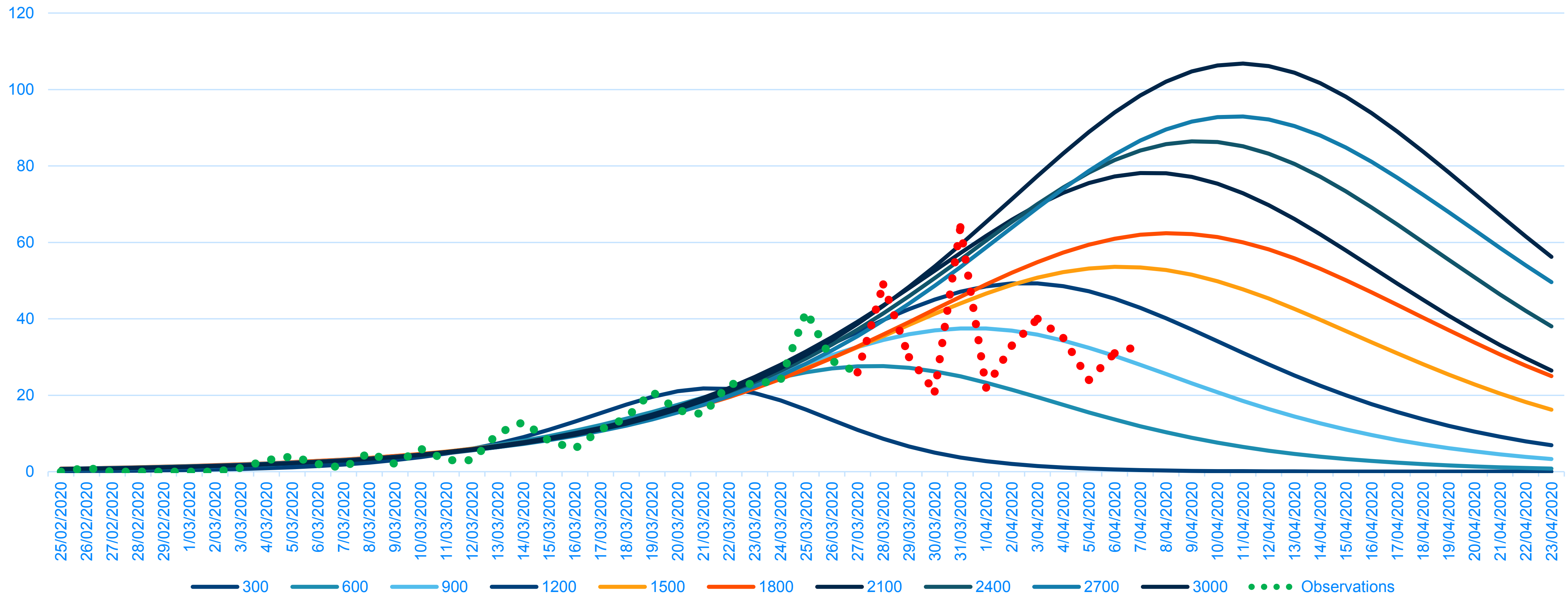
# Veneto



3000
2500
2000
1500
1000
500
0
24/02/2020
23/04/2020
300
600
900
1200
1500
1800
2100
2400
2700
3000
Observations

# Veneto

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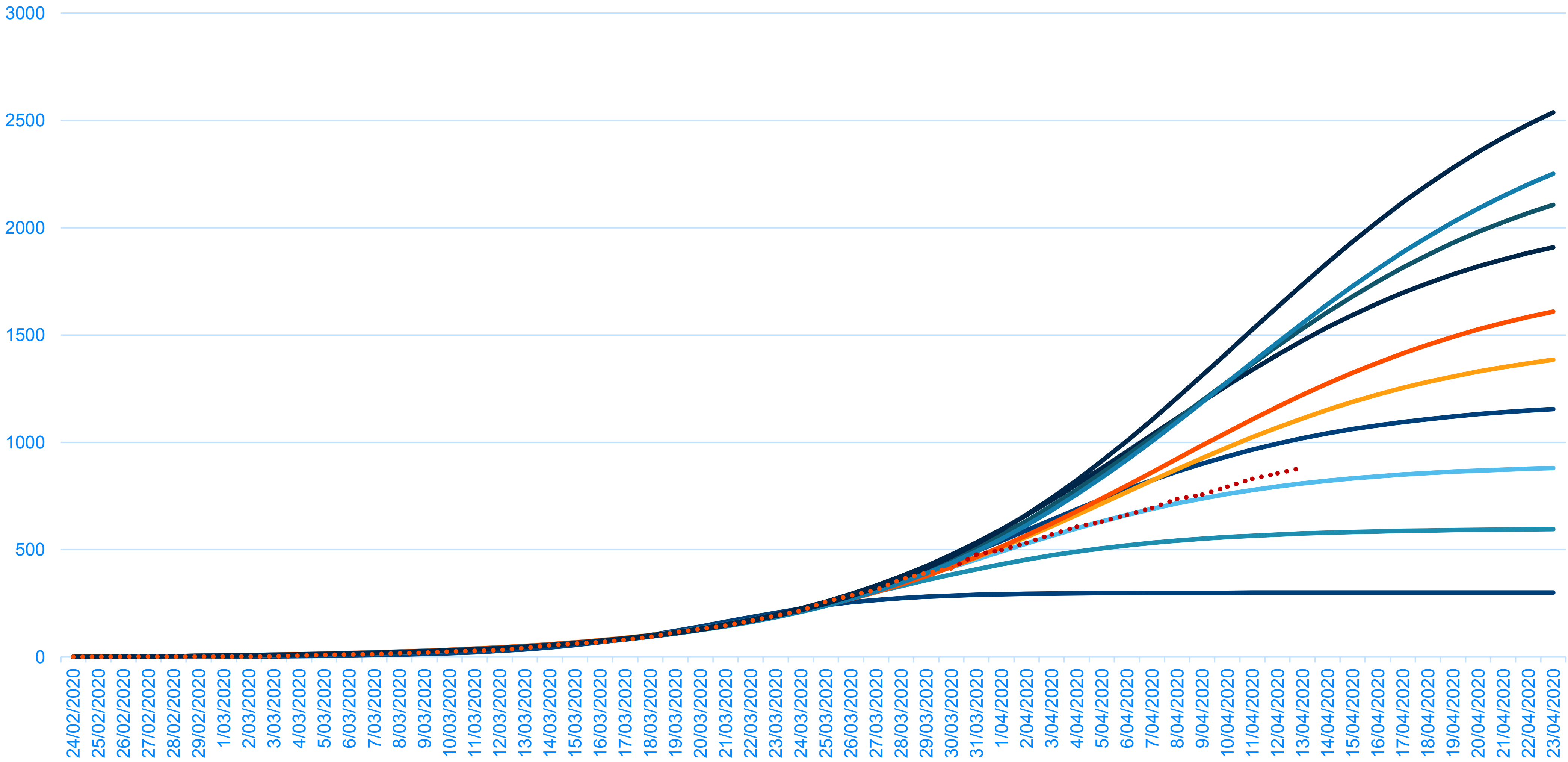
# Veneto – Update 14/04

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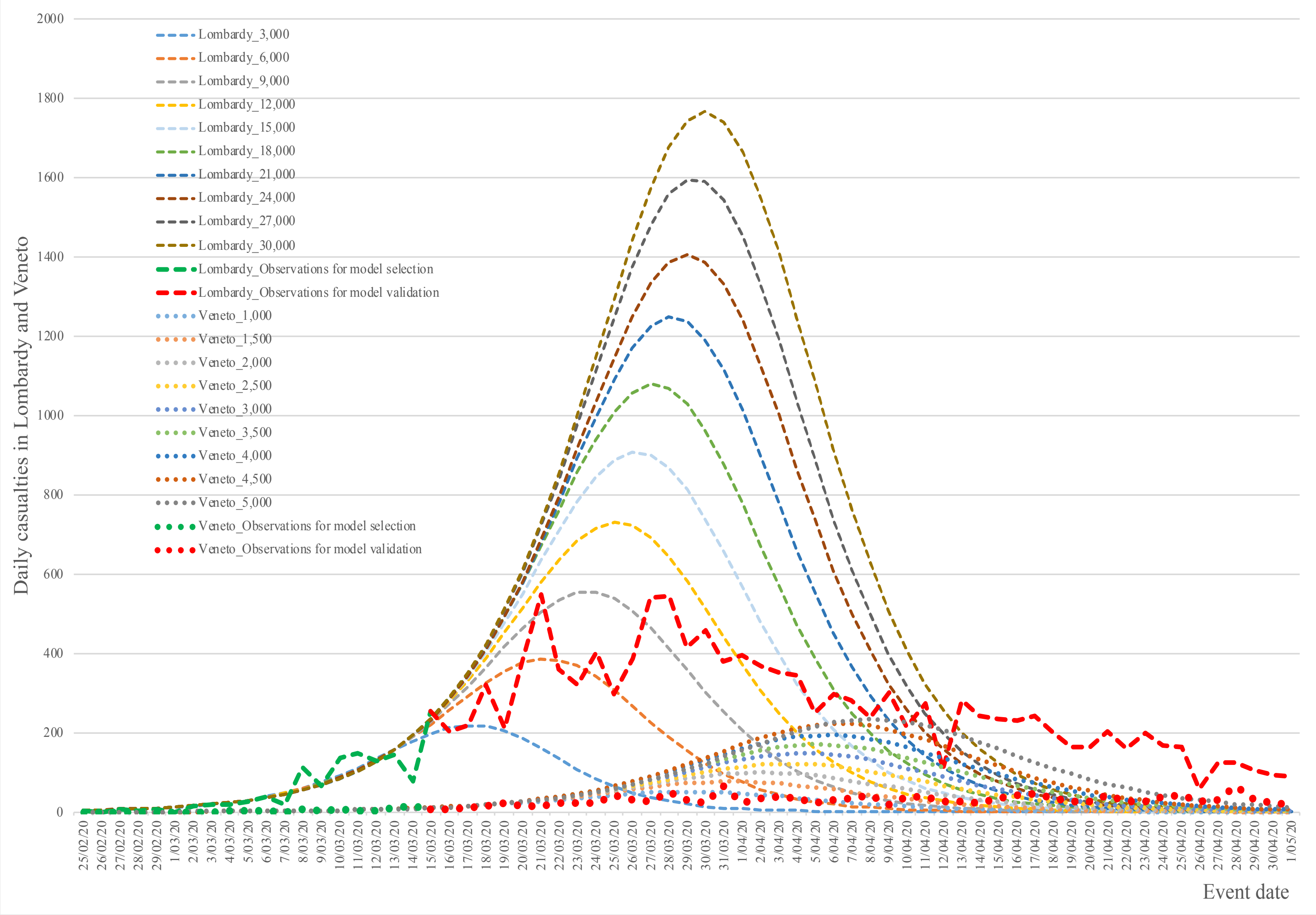
# Lombardy versus Veneto

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# 4. ICU occupation in Belgium

**Insights from:**

- Decock, K., Debackere, K., Vandamme A.-M. and Van Looy, B. (2020). Scenario-driven Forecasting: Lessons Learned from Modeling the COVID-19 Pandemic. *ISSI Newsletter,* Vol. 16, Iss. 1., pp. 2-6
- Decock, K., Debackere, K., Vandamme A.-M. and Van Looy, B. (2020). Scenario-driven Forecasting: Modeling peaks and paths. Insights from the COVID-19 Pandemic in Belgium. *Under review.*

# The Belgium Case: Data

- 03/02/2020: First confirmed case
- 10/03/2020: Fist COVID-19 deceased registered
- Initial ICU capacity: 1.650 beds in total
- Gradual increase towards approx. 2.300 ICU beds exclusively for COVID-19 patients
- Will this be enough for the coming weeks/months?

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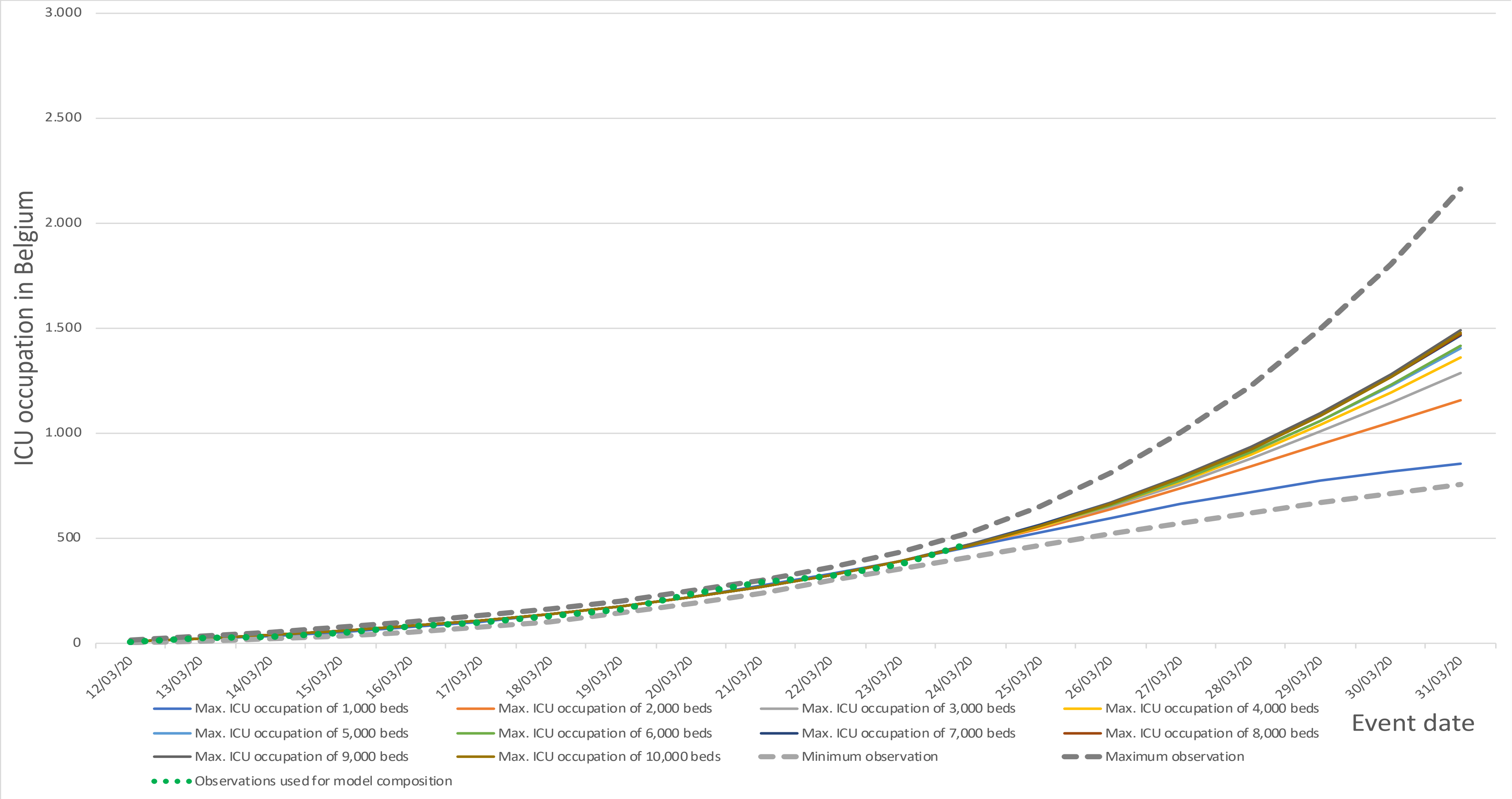
# COVID-19 ICU occupation between 12/03 - 24/03/2020

| Date | ICU occupation | Date | ICU occupation | Date | ICU occupation |
|---|---|---|---|---|---|
| 12/03/20 | 5 | 17/03/20 | 100 | 22/03/20 | 322 |
| 13/03/20 | 24 | 18/03/20 | 130 | 23/03/20 | 381 |
| 14/03/20 | 33 | 19/03/20 | 164 | 24/03/20 | 474 |
| 15/03/20 | 53 | 20/03/20 | 238 | | |
| 16/03/20 | 79 | 21/03/20 | 290 | | |

Source: Sciensano

# Stylized pathways of more likely scenarios – zoom-in

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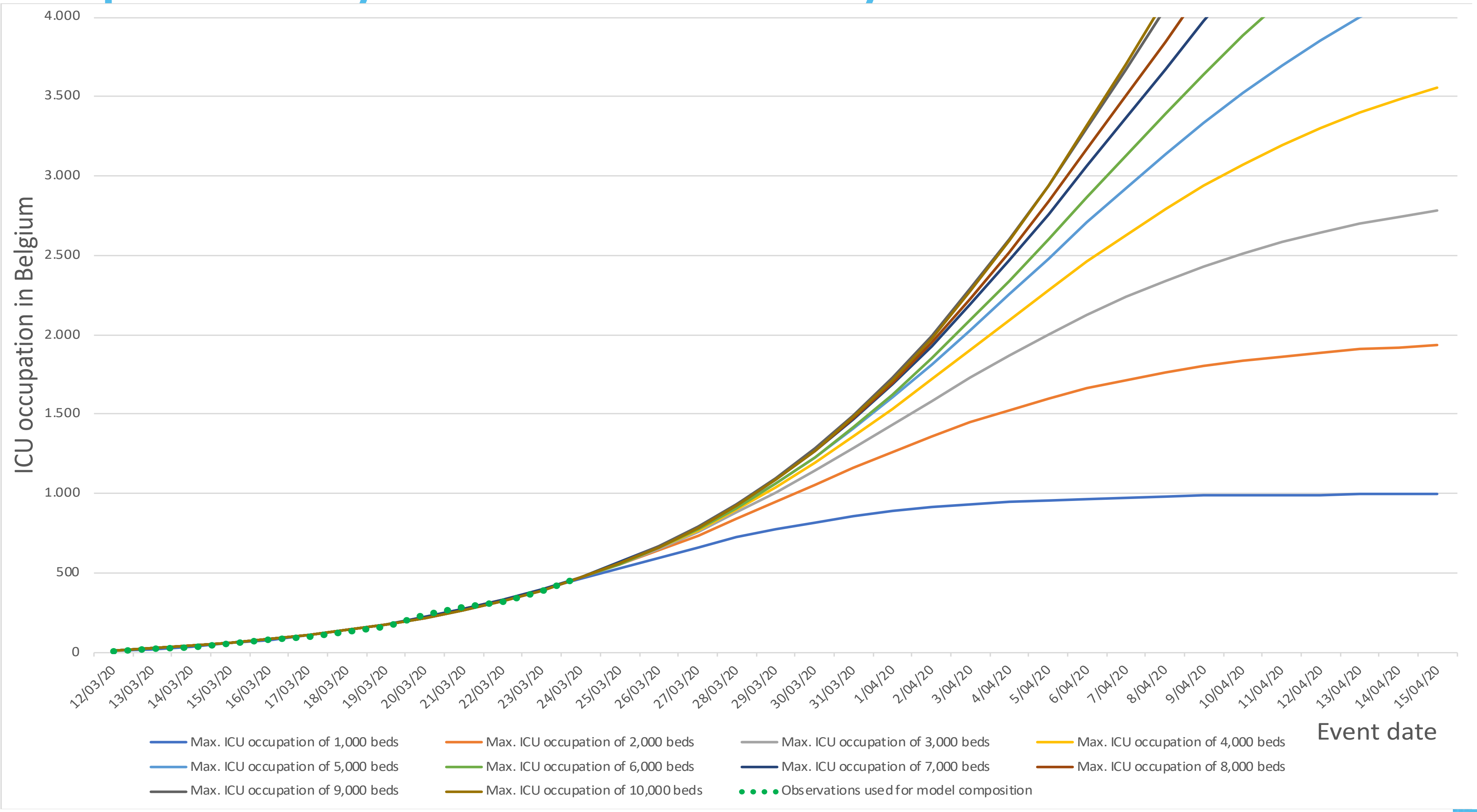
# Stylized pathways of more likely scenarios – zoom-out



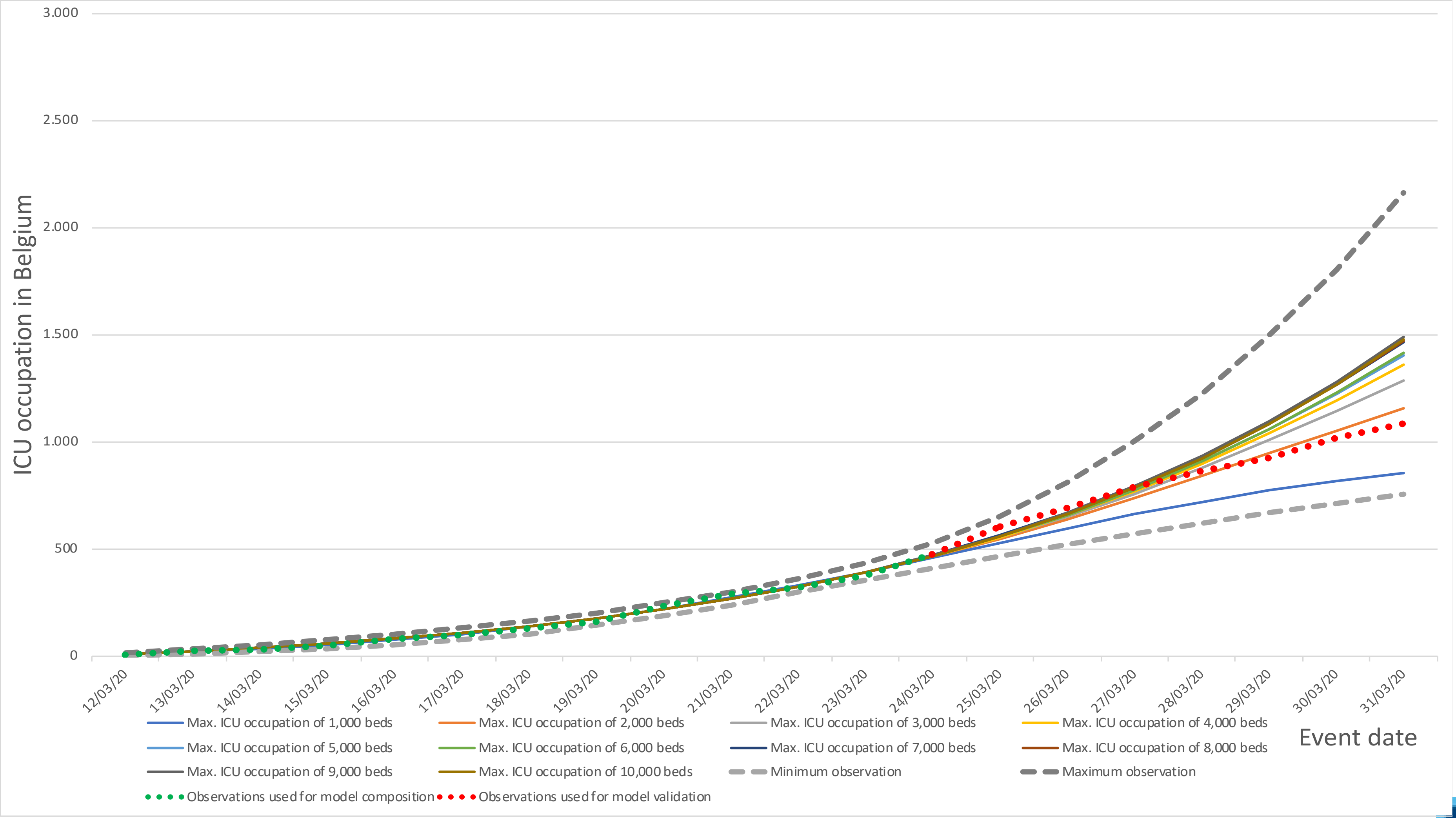
# Forecasting the ICU occupation between 25-31/03/2020

| | Average ICU occupation for the corresponding pathways | | | | | | |
|---|---|---|---|---|---|---|---|
| **Max. ICU capacity** | **25/03/20** | **26/03/20** | **27/03/20** | **28/03/20** | **29/03/20** | **30/03/20** | **31/03/20** |
| 1,000 | 530.41 | 598.30 | 662.88 | 722.03 | 774.37 | 819.26 | 856.77 |
| 2,000 | 549.63 | 640.24 | 737.86 | 840.94 | 947.44 | 1,054.95 | 1,160.93 |
| 3,000 | 554.59 | 651.96 | 760.39 | 879.53 | 1,008.49 | 1,145.73 | 1,289.10 |
| 4,000 | 556.01 | 656.58 | 770.32 | 897.71 | 1,038.78 | 1,192.99 | 1,359.08 |
| 5,000 | 560.06 | 662.81 | 780.00 | 912.65 | 1,061.44 | 1,226.54 | 1,407.53 |
| 6,000 | 557.22 | 659.75 | 777.21 | 910.96 | 1,062.18 | 1,231.69 | 1,419.82 |
| 7,000 | 565.75 | 671.08 | 792.29 | 931.05 | 1,088.92 | 1,267.17 | 1,466.65 |
| 8,000 | 560.28 | 665.33 | 786.64 | 926.13 | 1,085.62 | 1,266.81 | 1,471.03 |
| 9,000 | 562.46 | 668.74 | 791.80 | 933.75 | 1,096.72 | 1,282.72 | 1,493.55 |
| 10,000 | 559.37 | 664.17 | 785.49 | 925.47 | 1,086.32 | 1,270.25 | 1,479.31 |
| Overall minimum | 467.52 | 520.39 | 571.98 | 621.99 | 669.57 | 713.99 | 754.72 |
| Overall maximum | 655.25 | 812.99 | 1,002.77 | 1,229.04 | 1,495.87 | 1,806.41 | 2,162.24 |
| Overall average | 545.50 | 631.60 | 723.48 | 820.43 | 921.78 | 1,026.99 | 1,135.52 |
| Average of the 10 end states | 555.58 | 653.90 | 764.49 | 888.02 | 1,025.03 | 1,175.81 | 1,340.38 |

# Forecasting the ICU occupation between 25-31/03/2020

| | Average ICU occupation for the corresponding pathways | | | | | | |
|---|---|---|---|---|---|---|---|
| **Max. ICU capacity** | **25/03/20** | **26/03/20** | **27/03/20** | **28/03/20** | **29/03/20** | **30/03/20** | **31/03/20** |
| 1,000 | 530.41 | 598.30 | 662.88 | 722.03 | 774.37 | 819.26 | 856.77 |
| 2,000 | 549.63 | 640.24 | 737.86 | 840.94 | 947.44 | 1,054.95 | 1,160.93 |
| 3,000 | 554.59 | 651.96 | 760.39 | 879.53 | 1,008.49 | 1,145.73 | 1,289.10 |
| 4,000 | 556.01 | 656.58 | 770.32 | 897.71 | 1,038.78 | 1,192.99 | 1,359.08 |
| 5,000 | 560.06 | 662.81 | 780.00 | 912.65 | 1,061.44 | 1,226.54 | 1,407.53 |
| 6,000 | 557.22 | 659.75 | 777.21 | 910.96 | 1,062.18 | 1,231.69 | 1,419.82 |
| 7,000 | 565.75 | 671.08 | 792.29 | 931.05 | 1,088.92 | 1,267.17 | 1,466.65 |
| 8,000 | 560.28 | 665.33 | 786.64 | 926.13 | 1,085.62 | 1,266.81 | 1,471.03 |
| 9,000 | 562.46 | 668.74 | 791.80 | 933.75 | 1,096.72 | 1,282.72 | 1,493.55 |
| 10,000 | 559.37 | 664.17 | 785.49 | 925.47 | 1,086.32 | 1,270.25 | 1,479.31 |
| Overall minimum | 467.52 | 520.39 | 571.98 | 621.99 | 669.57 | 713.99 | 754.72 |
| Overall maximum | 655.25 | 812.99 | 1,002.77 | 1,229.04 | 1,495.87 | 1,806.41 | 2,162.24 |
| Overall average | 545.50 | 631.60 | 723.48 | 820.43 | 921.78 | 1,026.99 | 1,135.52 |
| Average of the 10 end states | 555.58 | 653.90 | 764.49 | 888.02 | 1,025.03 | 1,175.81 | 1,340.38 |
| ***Actuals*** | ***605*** | ***690*** | ***789*** | ***867*** | ***927*** | ***1,021*** | ***1,088*** |

# Short term evolution of ICU occupation in Belgium

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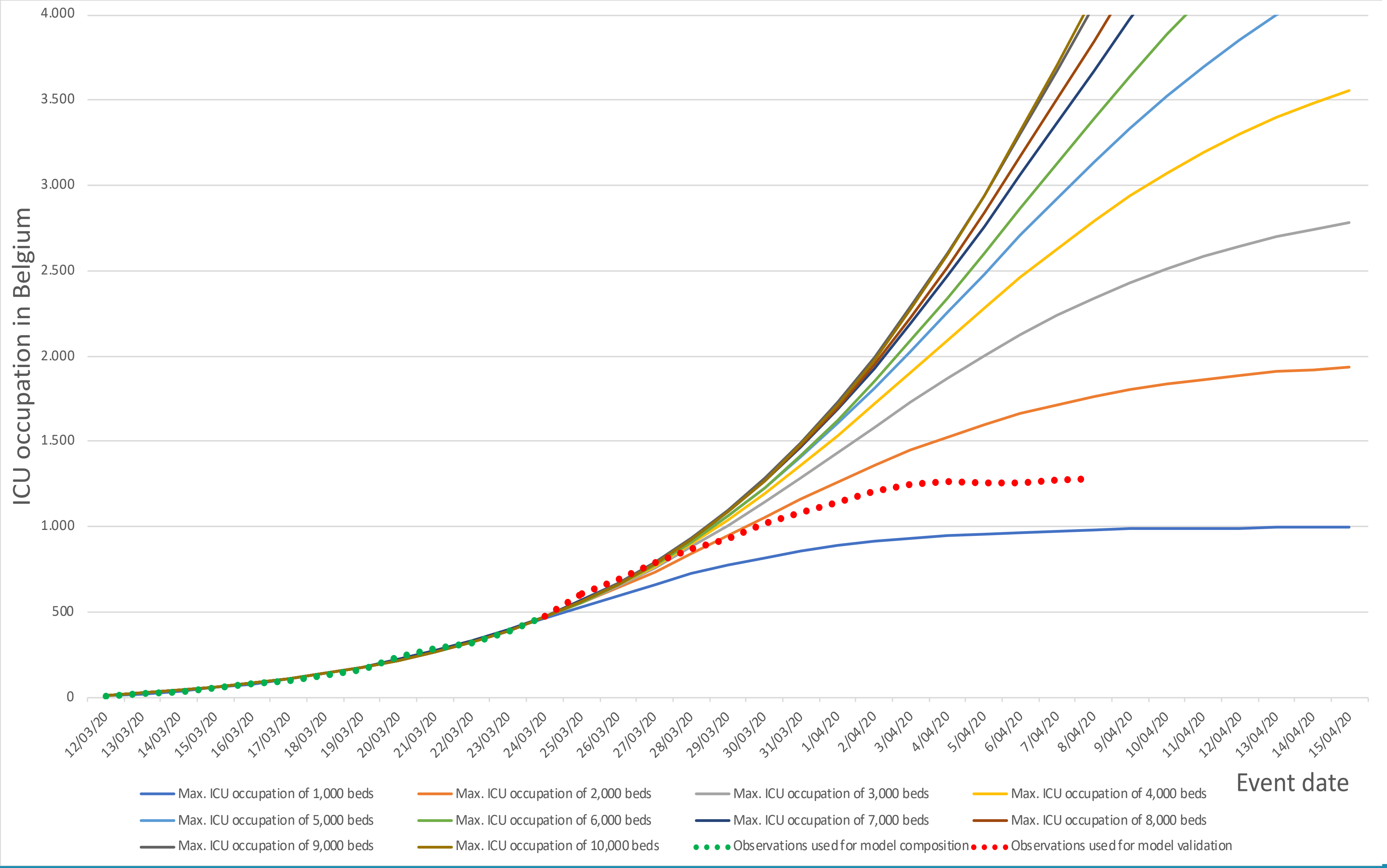
# COVID-19 ICU occupation between 25/03 - 08/04/2020

| Date | ICU occupation | Date | ICU occupation | Date | ICU occupation |
|---|---|---|---|---|---|
| 25/03/20 | 605 | 30/03/20 | 1,021 | 4/04/20 | 1,261 |
| 26/03/20 | 690 | 31/03/20 | 1,088 | 5/04/20 | 1,257 |
| 27/03/20 | 789 | 1/04/20 | 1,144 | 6/04/20 | 1,260 |
| 28/03/20 | 867 | 2/04/20 | 1,205 | 7/04/20 | 1,276 |
| 29/03/20 | 927 | 3/04/20 | 1,245 | 8/04/20 | 1,285 |

Source: Sciensano

# Long term evolution of ICU occupation in Belgium

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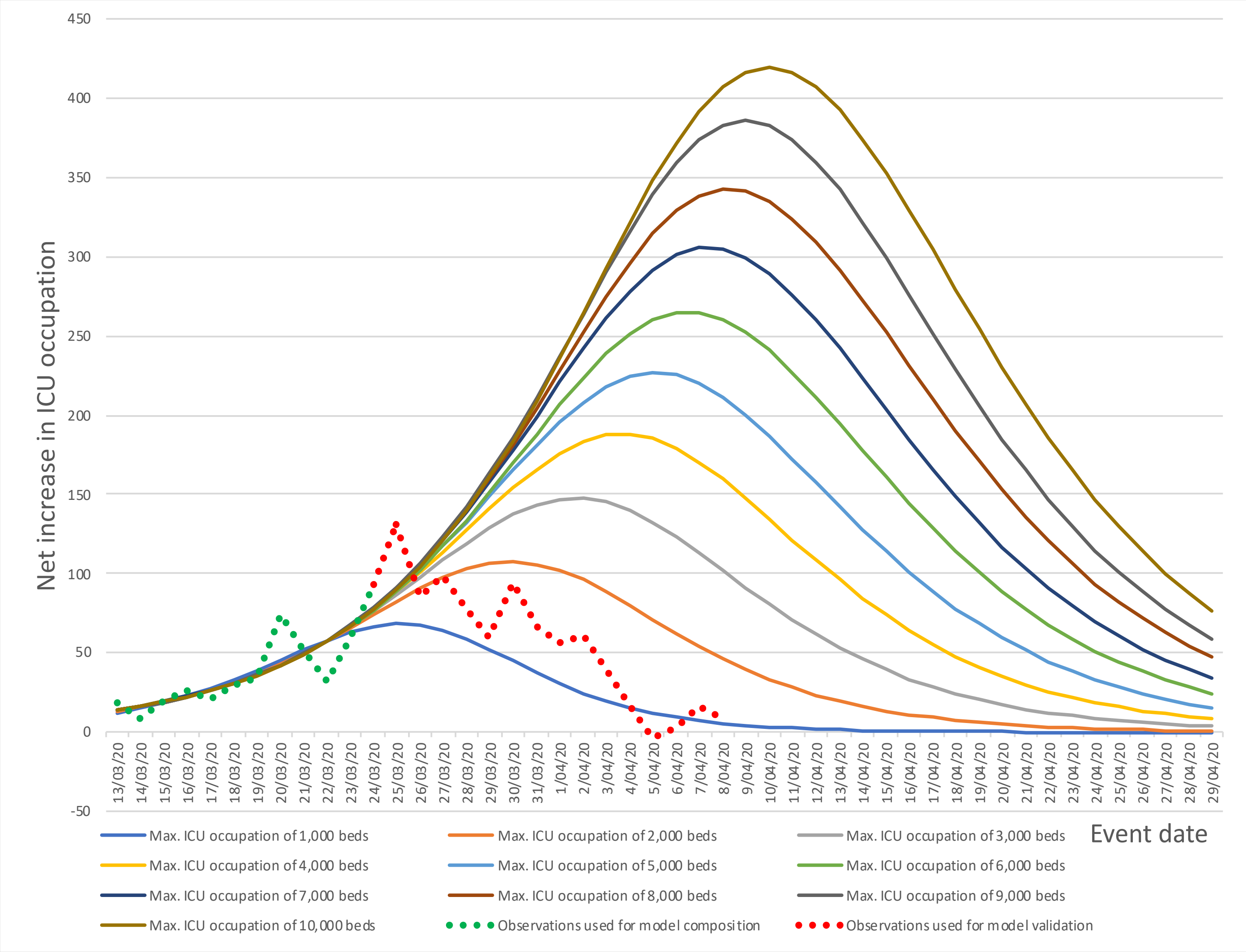
# Daily net increase in ICU occupation



# Conclusions

- Epidemiological models (e.g. Bayesian SEIR modelling) suffer from accuracy since the basic epidemiological parameters are unknown during the early phases of the emerging virus.

- At such critical moments during an unfolding crisis, scenario-driven forecasting serves as a valid complement for other modelling efforts.

- This dynamic blending has the potential to inform policy makers with accurate predictions in the short term and signal plausible end-states in the scenario portfolio when additional observations become available (requiring temporal distance).

- Our combination of forecast and foresight hence does not signal yet another case in evidence-based policy, but it rather illustrates the good governance of evidence as advocated by Parkhurst (2016).

# 5. Deceased in Belgium

**Insights from:**

Decock, K., Bergamini, M., Debackere, K., Lupi, E., Vandamme A.-M. and Van Looy, B. (2020). Predicting when peaks will occur, ex ante: Insights from the COVID-19 Pandemic in Italy and Belgium. *Under review*

# “Forced quarantaine” in the elderly care centers

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## Vlaamse rusthuizen vragen verbod op bezoek in verband met coronacrisis

11/03/20 om 11:40 Bijgewerkt om 11:39

Knack

## 11 MAART 2020; 18U: PERSBERICHT: WOONZORGCENTRA MOETEN DEUREN SLUITEN VOOR ALLE EXTERNE BEZOEKERS

Deze avond werd een **nieuw persbericht** ontvangen vanuit het kabinet van minister Beke.

**Vanaf donderdag 12 maart 2020 moeten woonzorgcentra de deuren sluiten voor alle externe bezoekers.**

DINSDAG 24 MAART 2020 - DS AVOND

CORONA: DE RUSTHUIZEN

## ‘Sommigen willen geen levensrekkend verblijf in het ziekenhuis’

dS +

## ‘Rusthuizen zijn een tikkende tijdbom’

27/03/2020 om 19:46 door Veerle Beel

KU LEUVEN

# Challenges – data quality / registering issues

- Before 31/03: 1 data point, related to the total deceased of the last 24 hours
- On 31/03: reporting of 2 data points, i.e.:
  - 98 as the daily number of deceased (of the last 24 hours)
  - 94 of deceased people since March 11 (retro-active corrections)
- Since then, additional retro-active corrections reported, e.g. on:
  - 02/04: 42 cases
  - 05/04: 43 cases
  - 06/04: 29 cases
- On 07/04: 272 cases related to elderly care homes were allocated from 01/04 till 04/04
- Also on 10/04: another 206 ‘old’ cases allocated between 18/03 and 06/04.

# From 10/04 onwards… “data issues” go public

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The Economist

Daily chart

## Tracking covid-19 excess deaths across countries

Official covid-19 death tolls still under-count the true number of fatalities

APR 16TH 2020

BBC NEWS

UK | England | N. Ireland | Scotland | Wales | Politics

## Coronavirus: Older people being 'airbrushed' out of virus figures

14 April 2020

de Volkskrant

NIEUWS CORONASTATISTIEK

## Huisartsen gaan zelf niet-geteste coronapatiënten bijhouden: beter beeld van virus in Nederland

Nederlandse huisartsen slaan de handen ineen om de coronastatistieken te verbeteren. Ze gaan de ernstig zieke patiënten en overledenen in kaart brengen, die niet op corona zijn getest maar van wie vrijwel zeker vaststaat dat ze besmet zijn of waren met het virus. Gezondheidsdienst RIVM is blij met het initiatief.

**Arnout le Clercq** 13 april 2020, 17:33

DE TIJD

16/04/2020

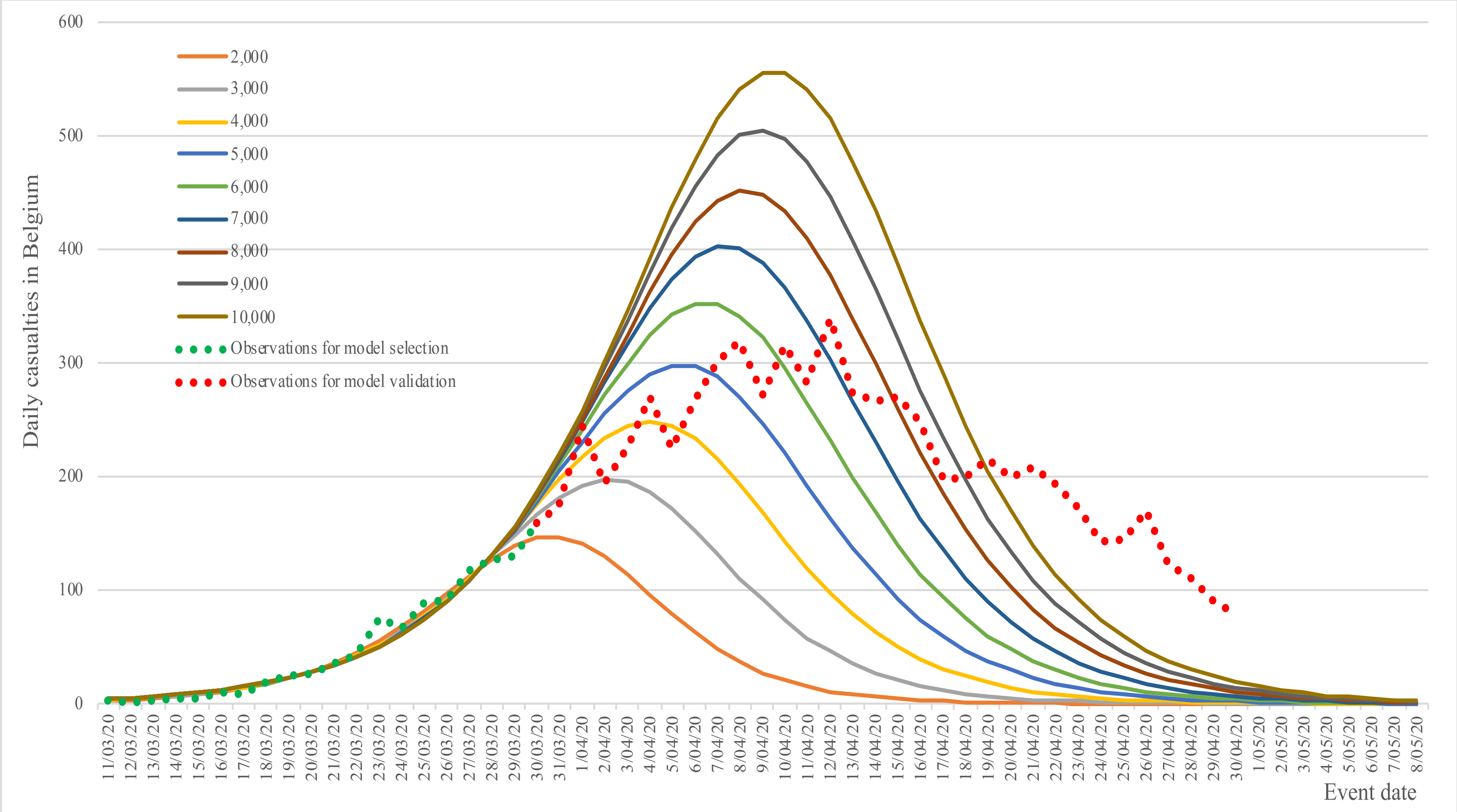
We gaan niet afwijken van het principe dat we zowel bevestigde als vermoedelijke gevallen tellen. Want dat is de standaardpraktijk.

Deel op

STEVEN VAN GUCHT
VIROLOOG VOLKSGEZONDHEID

KU LEUVEN

# Daily number of casualties

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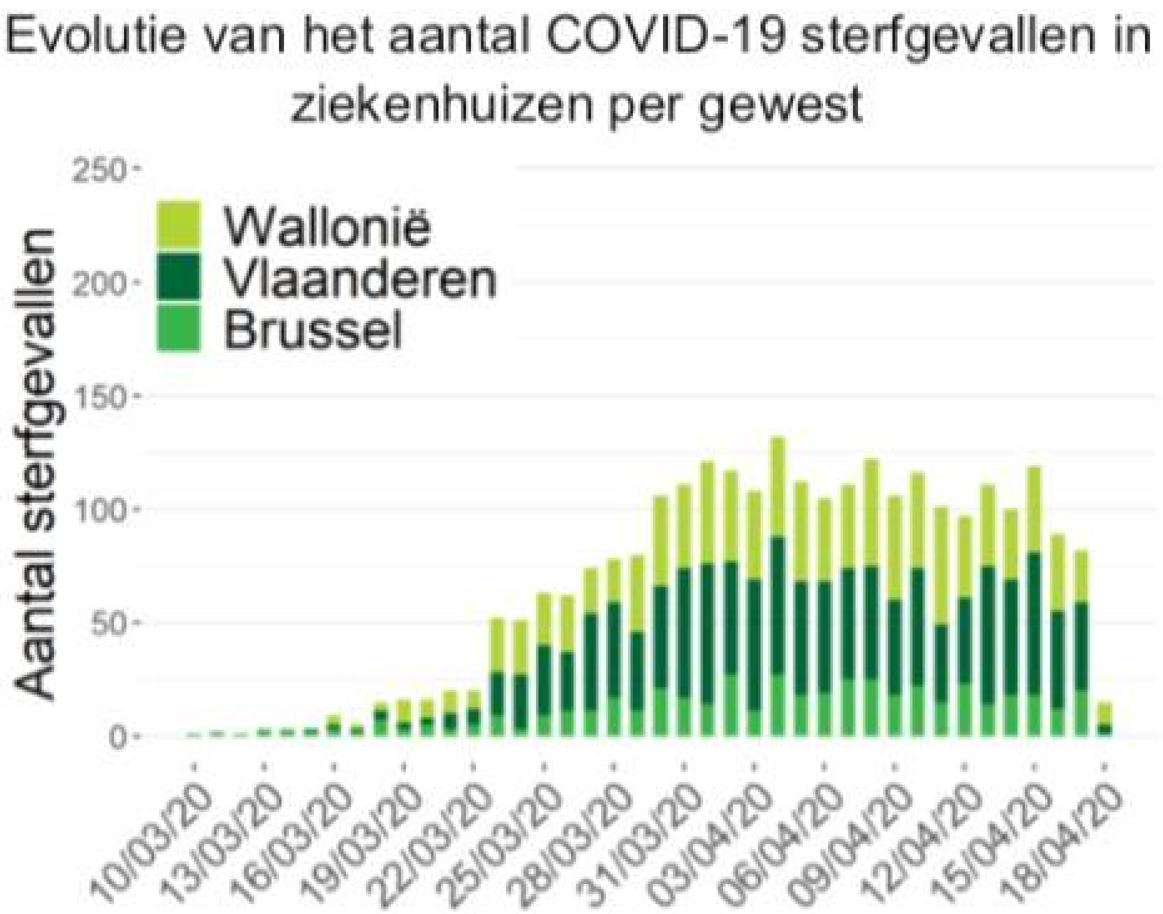
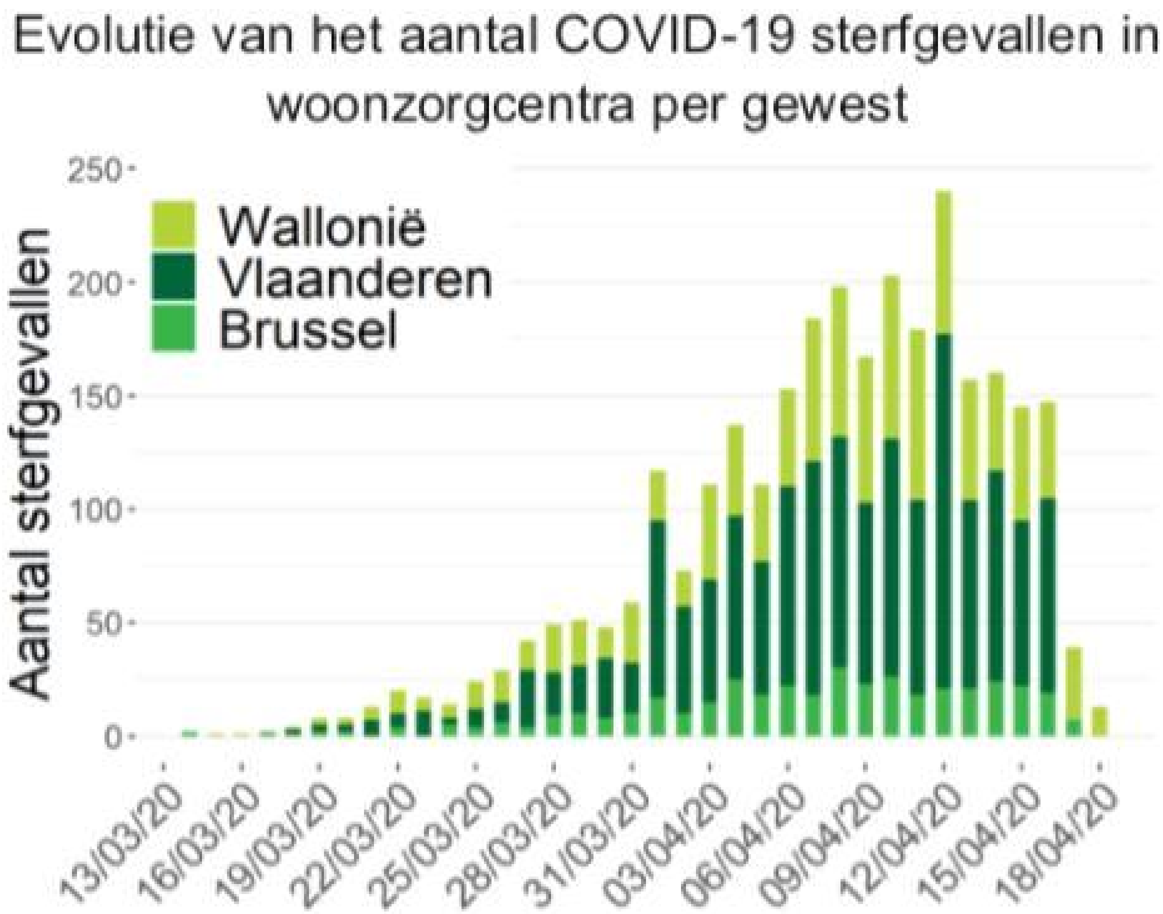
# Not one curve, but at least two curves to be modeled…

- Underlying (growth) dynamics are different between deceased in the hospitals and deceased outside the hospitals (e.g. elderly care homes)
  - Started later, no direct imports from abroad;
  - Higher contamination due to the location-specific circumstances;
  - Higher death ratio (age, other type (lack) of medical support / equipment, …);
  - Other age-related issues (more “pre-existing conditions” like diabetes, cardiac problem… );
  - Real cause of death (i.e. hospitals) VS Presumed cause of death (i.e. care homes; only 2,8% of the deaths has been COVID-19 confirmed by a lab test);
  - Different stages of the underlying sub-epidemics (affecting the R-value).

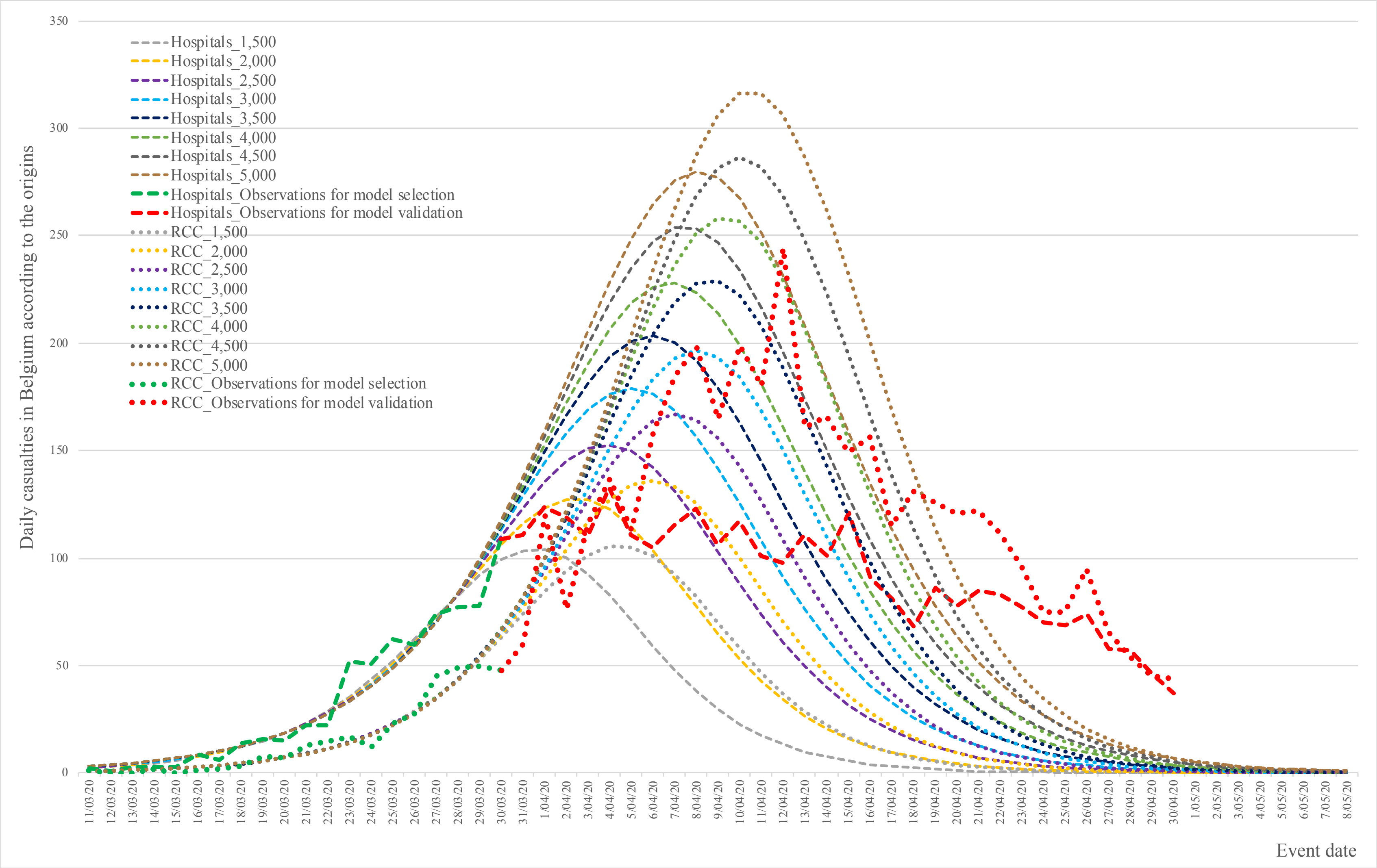
- As such, the two curves need to be modeled separately, as the sum of two S-curves results not always an new S-curve… (other peaks to be reached).

# Disentangled curves?!

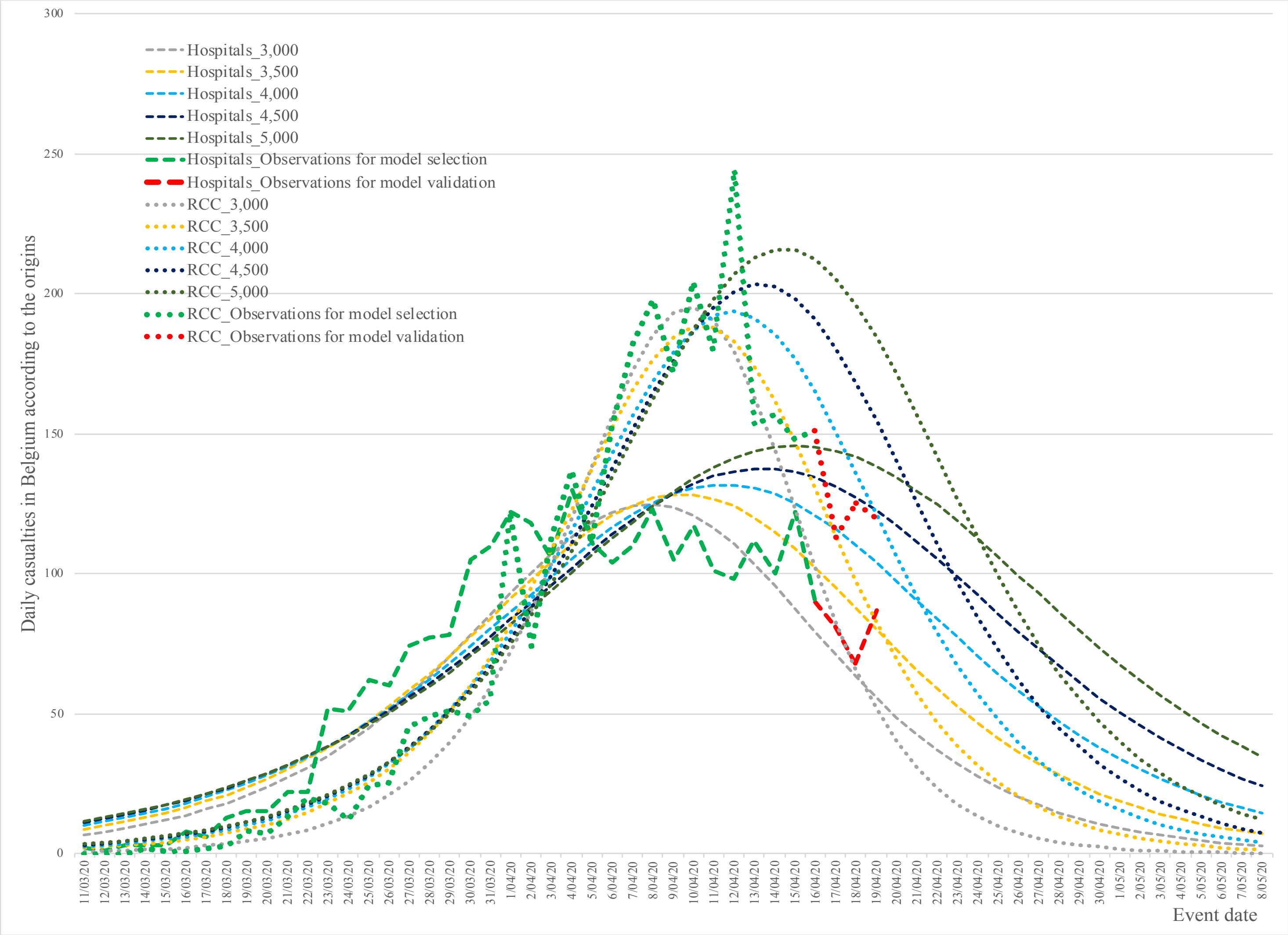


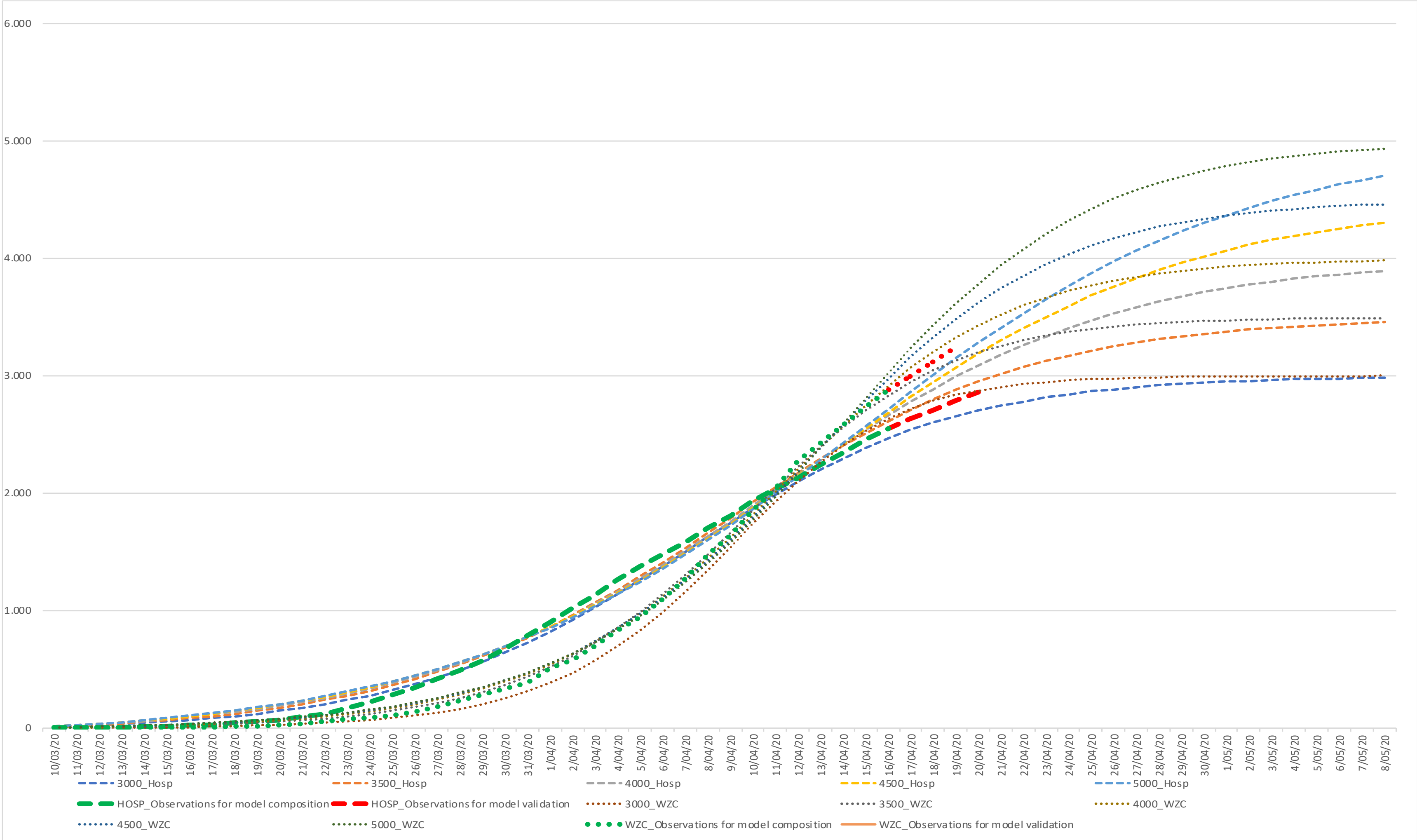
# Hospitals versus elderly care homes – DAILY



# Model updates – 2 weeks later



# Hospitals versus elderly care homes – CUMUL



# Key takeaways

FLANDERS BUSINESS SCHOOL
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1. Scenario-driven forecasting: 1 + 1. Becomes 3?
2. Predictive ability of the outcomes depends critically on reliable / complete / consistent data (incl. separate time series)!
3. Short term accuracy: high (ex ante) – contributing to decision making under ‘Knightian’ uncertainty
4. Importance of understanding the context: impact on the underlying growth dynamics
5. Dis-aggregation (including the reverse logic)
6. ‘Peaks <> End States (flattening of the curves, cohorts, data…)

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