Institute and Faculty of Actuaries

The IFoA Conference 2022

22–23 June – etc.venues, 133 Houndsditch, London

Institute
and Faculty
of Actuaries

Advancing Analytics with COVID-19

Louis Rossouw
Rob Kaner

COVID-19 Activities

During COVID-19

- R estimates
- COVID-19 models
- Understanding experience
- Uncertainty!

Learnings?

- Continuous
  - Sourcing data
  - Managing
  - Regular analysis
- Keeping track of it all
- Efficiency
- Handling uncertainty

Institute and Faculty of Actuaries

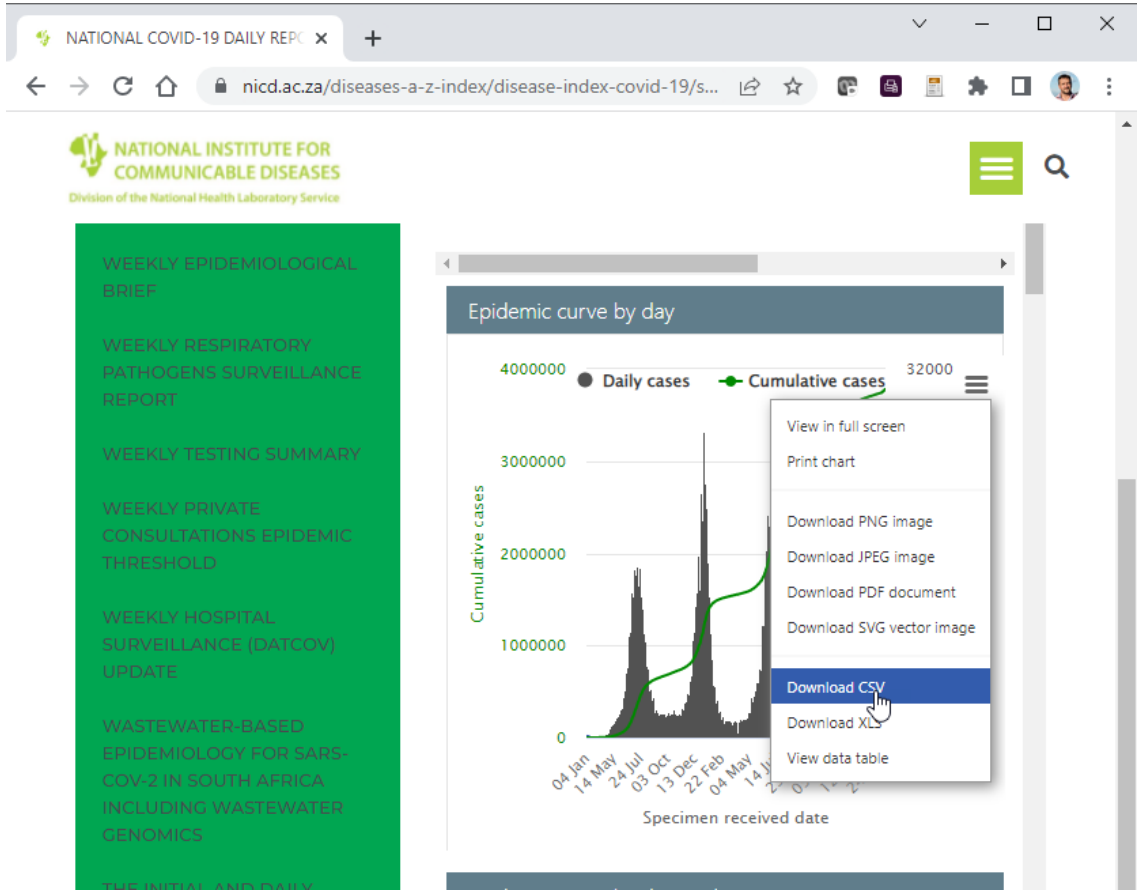
Estimating R

$$E(I_t) = R_t \sum_{s=1}^{t} I_{t-s} w_s$$

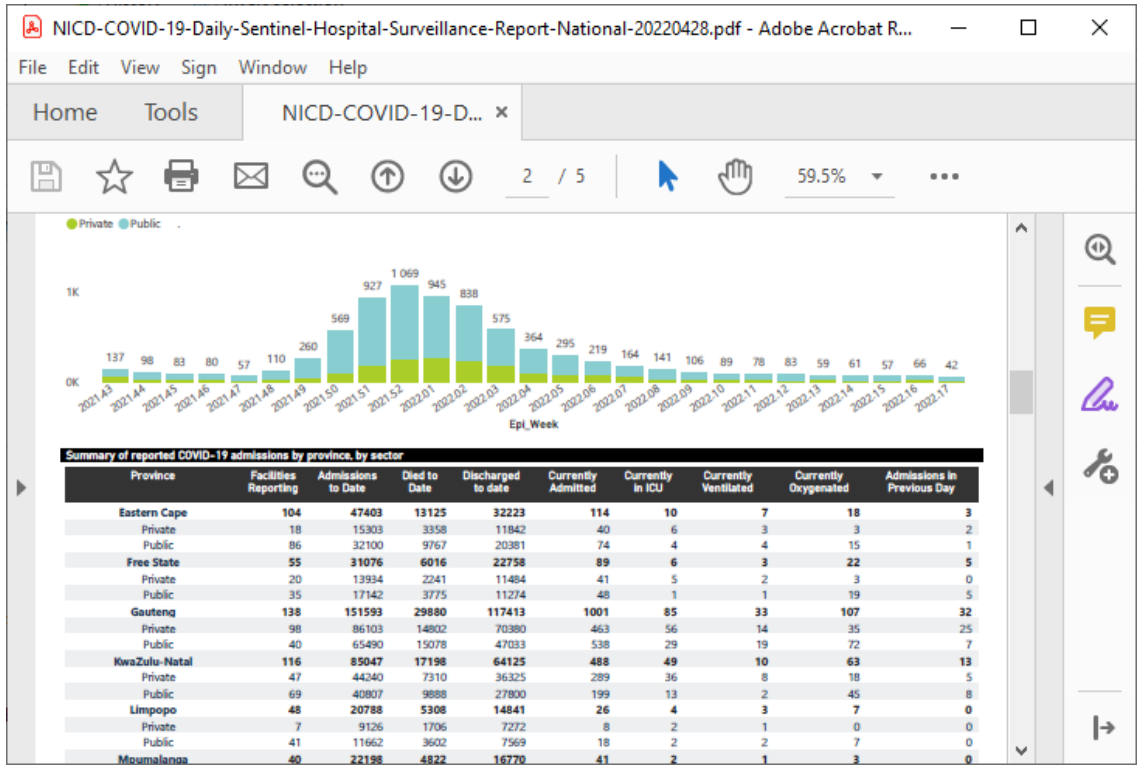
- I_t is infections on a day
- R_t is instantaneous reproduction number
- w_s is the generation interval (how infectious one is over time)
- Can use cases, admissions, deaths…

Cori, A. *et al.* (2013) 'A new framework and software to estimate time-varying reproduction numbers during epidemics', *American Journal of Epidemiology*, 178(9), pp. 1505–1512. doi:10.1093/aje/kwt133.

Data sources – Dashboard and PDFs



National Institute for Communicable Diseases (2021) *National COVID-19 Daily Report*. Available at: https://www.nicd.ac.za/diseases-a-z-index/covid-19/surveillance-reports/national-covid-19-daily-report/.

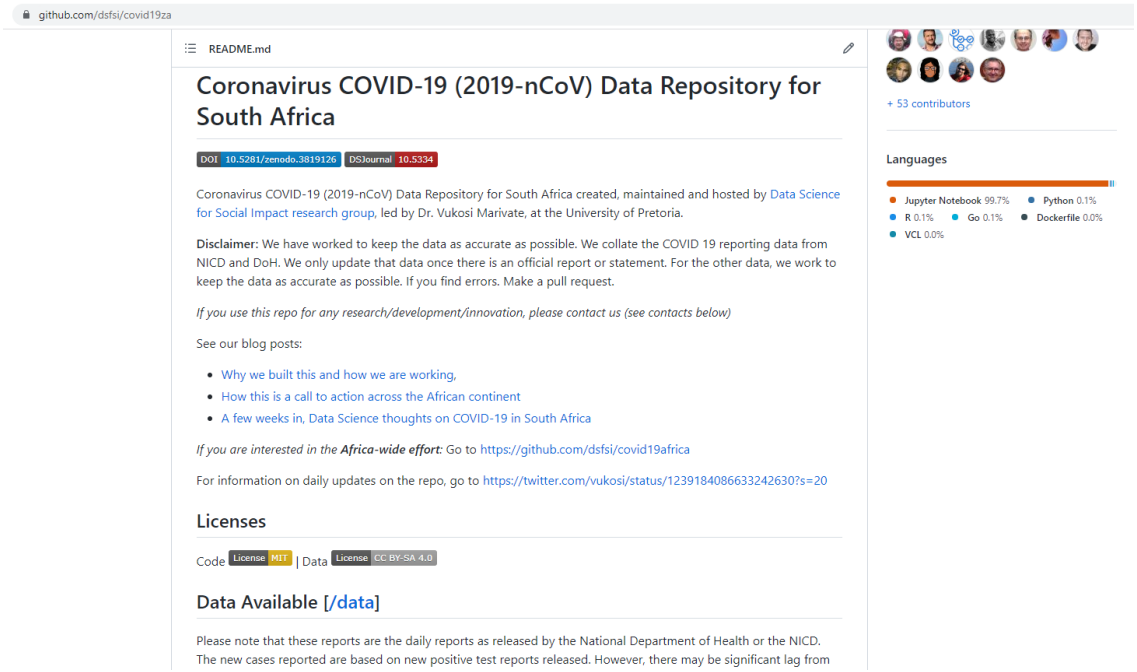


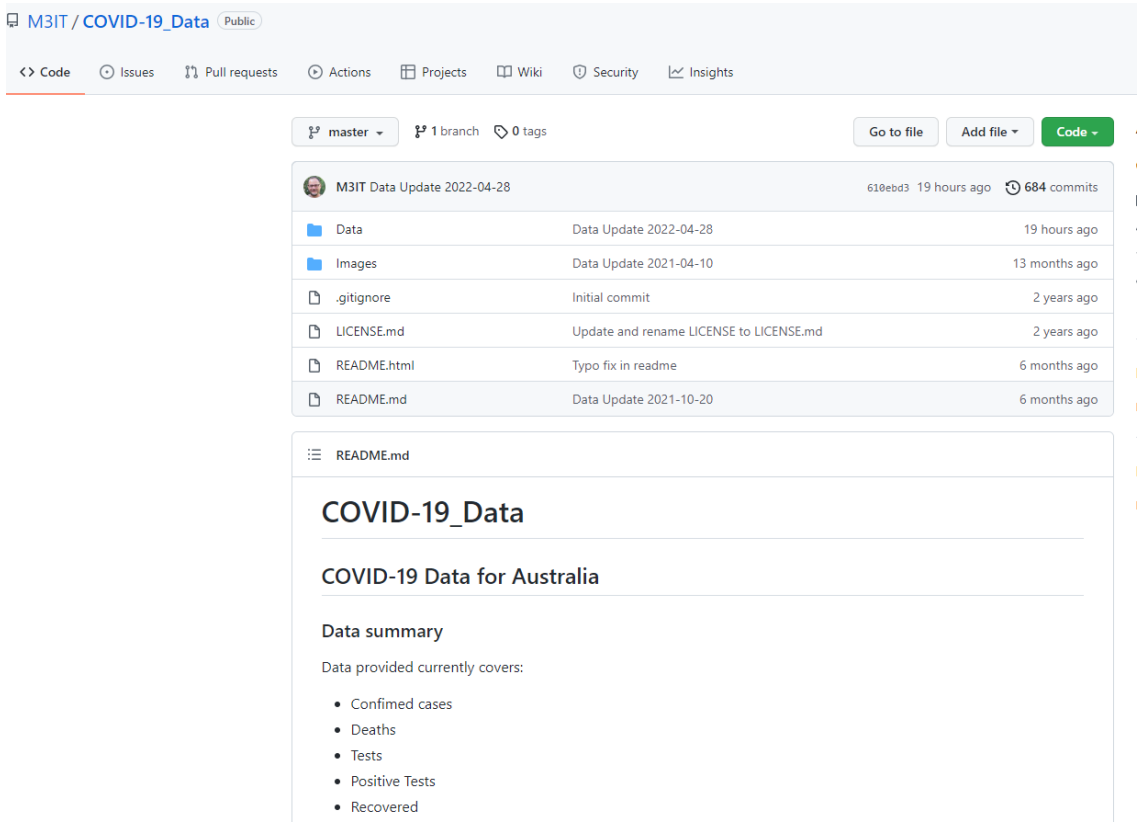
Province	Facilities Reporting	Admissions to Date	Died to Date	Discharged to date	Currently Admitted	Currently in ICU	Currently Ventilated	Currently Oxygenated	Admissions in Previous Day
Eastern Cape	**104**	**47403**	**13125**	**32223**	**114**	**10**	**7**	**18**	**3**
Private	18	15303	3358	11842	40	6	3	3	2
Public	86	32100	9767	20381	74	4	4	15	1
Free State	**55**	**31076**	**6016**	**22758**	**89**	**6**	**3**	**22**	**5**
Private	20	13934	2241	11484	41	5	2	3	0
Public	35	17142	3775	11274	48	1	1	19	5
Gauteng	**138**	**151593**	**29880**	**117413**	**1001**	**85**	**33**	**107**	**32**
Private	98	86103	14802	70380	463	56	14	35	25
Public	40	65490	15078	47033	538	29	19	72	7
KwaZulu-Natal	**116**	**85047**	**17198**	**64125**	**488**	**49**	**10**	**63**	**13**
Private	47	44240	7310	36325	289	36	8	18	5
Public	69	40807	9888	27800	199	13	2	45	8
Limpopo	**48**	**20788**	**5308**	**14841**	**26**	**4**	**3**	**7**	**0**
Private	7	9126	1706	7272	8	2	1	0	0
Public	41	11662	3602	7569	18	2	2	7	0
Mpumalanga	**40**	**22198**	**4822**	**16770**	**41**	**2**	**1**	**3**	**0**

National Institute for Communicable Diseases (2021) *Daily Hospital Surveillance (DATCOV) Report*. Available at: https://www.nicd.ac.za/diseases-a-z-index/disease-index-covid-19/surveillance-reports/daily-hospital-surveillance-datcov-report/.

Institute and Faculty of Actuaries

Open Data Sources



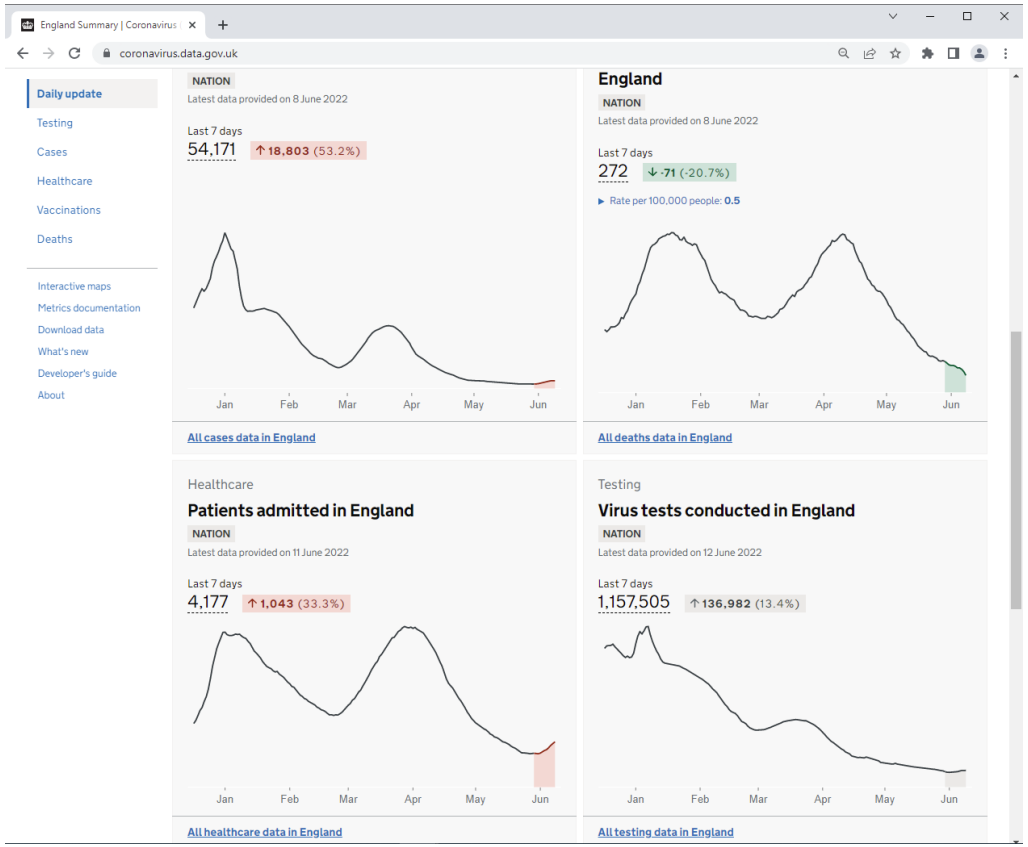


Marivate, V. *et al.* (2020) 'Coronavirus disease (COVID-19) case data - South Africa'. Zenodo. doi:10.5281/ZENODO.3888499.

O'Brien, J. *et al.* (2021) *Coronavirus (COVID-19) in Australia*, *COVID-19-data-aus*. Available at: https://www.covid19data.com.au (Accessed: 29 December 2021).

Institute and Faculty of Actuaries

Data sources – Dashboard and APIs



UK Government summary dashboard for COVID-19 in England.
Available at: https://coronavirus.data.gov.uk/

Open Data API — v.1

Table of contents

https://coronavirus.data.gov.uk/details/developers-guide/main-api

Institute and Faculty of Actuaries

Open & Machine-Readable Data

Old Way

- Capture data
- Download
  - Spreadsheet
  - Report
  - PDF
  - Use export to Excel
- Fix data in Excel

New Way

- Already captured
- Read data
  - from API
  - Website
  - Database
- Use scripts to transform data

Chain Ladders

Rick McCharles

$$\ln\left(\theta^{t,d}\right) \approx \sum_i x'_i \beta'_i + \sum_j x''_j \beta''_j$$

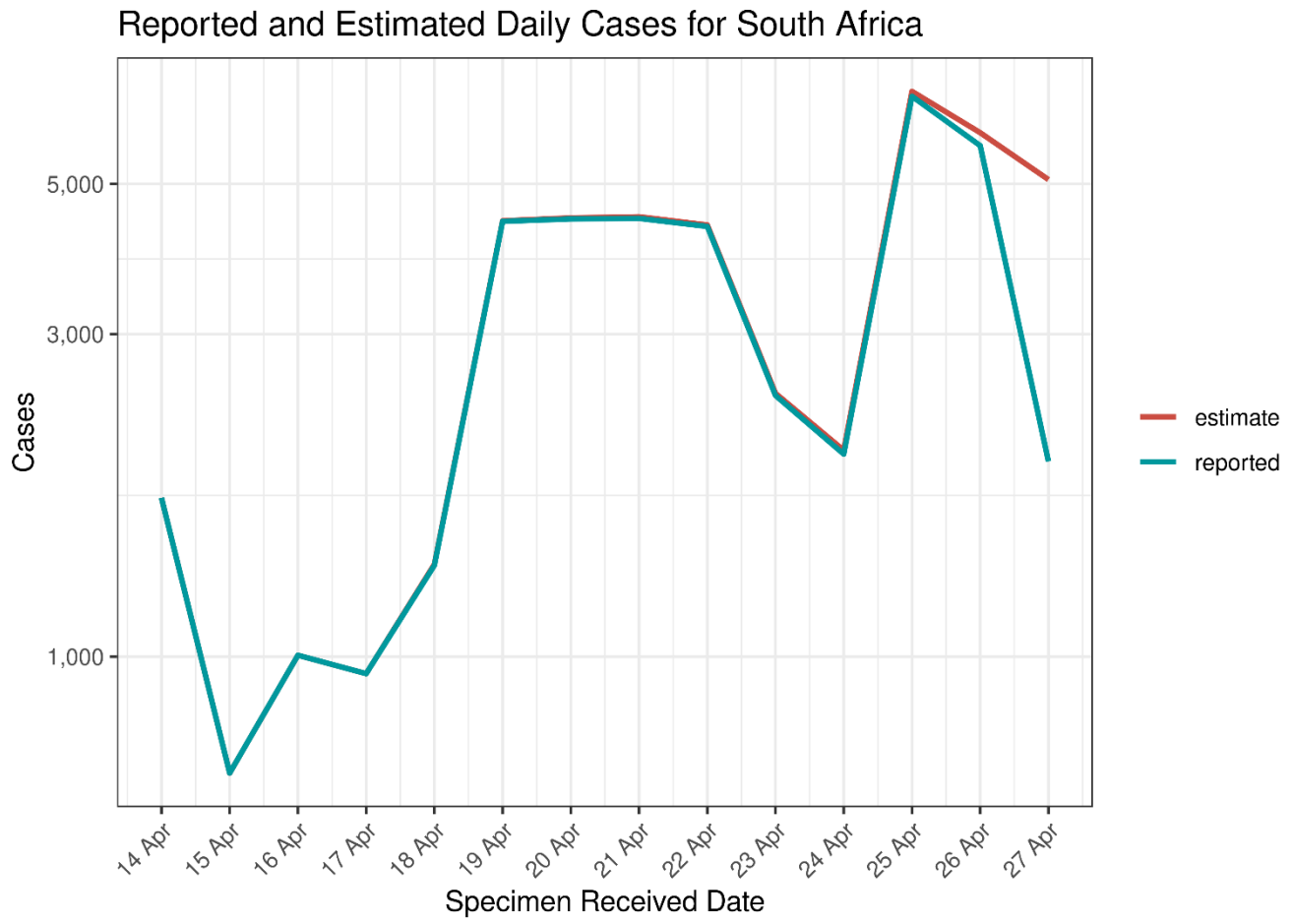
$$x'_i = \begin{cases} 1, i = t \\ 0, i \neq t \end{cases} \qquad x''_j = \begin{cases} 1, j = d \\ 0, j \neq d \end{cases}$$

- That is a GLM!
- Allows automation
- Generalised by adding more fields
- Apply other ML techniques…

Institute and Faculty of Actuaries

Rossouw, L. and Richman, R. (2019) 'Using machine learning to model claims experience and reporting delays for pricing and reserving', in. *Actuarial Society of South Africa Convention 2019*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3465424.

Allowance for late reported cases



Institute and Faculty of Actuaries

Estimating R with R

- R contains many packages
- All open source
- *ukcovid19*
  - Access UK COVID-19 data
- *EpiEstim*
  - Model R_t
  - Allowing for uncertainty

R Core Team (2019) *R: A language and environment for statistical computing*. manual. Vienna, Austria. Available at: https://www.R-project.org/.

Cori, A. (2013) *EpiEstim: A package to estimate time varying reproduction numbers from epidemic curves.* manual. Available at: https://CRAN.R-project.org/package=EpiEstim.

Code Versioning (using git)

Code Changes

Remove negative excess deaths.	Louis Rossouw <lrossouw@genre. 3/30/22	e68e56e6
Extend run-off use_days.	Louis Rossouw <lrossouw@genre. 3/14/22	7b849326
Accept being out by 1 on counts deaths in CA (spreading deaths repo	Louis Rossouw <lrossouw@genre. 3/9/22	b2c2a3a4
Fix ZA excess deaths range for weekly excess.	Louis Rossouw <lrossouw@genre. 2/17/22	4e0c9c33
Update packages.	Louis Rossouw <lrossouw@genre. 2/17/22	7df35861
Remove maxima on plots.	Louis Rossouw <lrossouw@genre. 1/24/22	60897450
Remove filtering of wide CIs	Louis Rossouw <lrossouw@genre. 1/24/22	a074a905
Update UK IBNR	Louis Rossouw <lrossouw@genre. 1/9/22	23afed4d
Save UK raw data.	Louis Rossouw <lrossouw@genre. 1/9/22	15716e38
Change the way r data files are saved for all countries.	Louis Rossouw <lrossouw@genre. 1/9/22	457743a0
Change gap for world to 24h	Louis Rossouw <lrossouw@genre. 1/9/22	8a40539e
Clear extra line	Louis Rossouw <lrossouw@genre. 1/9/22	7671a4d8
Fix bug in update.R	Louis Rossouw <lrossouw@genre. 1/9/22	123e3eae
Add logging of running_update	Louis Rossouw <lrossouw@genre. 1/9/22	2f8c6649
Revamp update script to be clever.	Louis Rossouw <lrossouw@genre. 1/9/22	a9f71153
Fix date on initial code for AU	Louis Rossouw <lrossouw@genre. 1/6/22	98a3edb7
Allow for trends in ZA IBNR	Louis Rossouw <lrossouw@genre. 1/6/22	d9b5dac9
Rename _sa_ to _za_ and _au_	Louis Rossouw <lrossouw@genre. 12/29/21	f2b05039
Fix AU fig.cap labels	Louis Rossouw <lrossouw@genre. 12/29/21	25ddb293
Fix AU state fig cap	Louis Rossouw <lrossouw@genre. 12/29/21	e22ae7db
Add lib scales to scratch data history	Louis Rossouw <lrossouw@genre. 12/29/21	93dd5b1b
Drop rna library (what was it?)	Louis Rossouw <lrossouw@genre. 12/29/21	2bc62c4f

Details of a specific change

estimating_r_au.Rmd

```
@@ -352,11 +352,10 @@ Rt_data <-
352 352       data %>% inner_join(
353 353         unique_area_types_rcalc[i, ],
354 354         by = c(
355         -         "report_date",
356 355           "area_type",
357 356           "country",
358 357           "state",
359         -         "district",
    358 +         "population",
360 359           "type"
361 360         )
362 361       )
@@ -411,7 +410,7 @@ Rt_data <-
411 410
412 411
413 412         # count cases
414         -       c_data <- a_data %>% select(area_type, country, state, district, type, date, count)
    413 +       c_data <- a_data %>% select(area_type, country, state, population, type, date, count)
415 414
416 415         c_Rt <- right_join(c_Rt, c_data, by = "date")
417 416
@@ -445,7 +444,7 @@ colnames(Rt_data) <- c(
445 444   "area_type",
446 445   "country",
447 446   "state",
448         - "district",
    447 + "population",
449 448   "type",
450 449   "count"
451 450 )
@@ -458,7 +457,7 @@ for (ci in c("50", "90", "95")) {
458 457     area_type = Rt_data$area_type,
459 458     country = Rt_data$country,
460 459     state = Rt_data$state,
461         -   district = Rt_data$district,
    460 +   population = Rt_data$population,
462 461     type = Rt_data$type,
463 462     ci = rep(paste0(ci, "%"), nrow(Rt_data)),
464 463     Rt_mean = Rt_data$Rt_mean,
```

Code = Document

R Markdown (code + document)

```
2814
2815 ### Reproduction Number
2816
2817 Below current (last weekly) effective reproduction number estimates are tabulated for South Africa and by
     province.
2818
2819 ```{r prep_table}
2820 # find the last estimates
2821 last_dates <- Rt_data %>%
2822   filter(!is.na(Rt_mean)) %>%
2823   group_by(area_type, country, province, district, type) %>%
2824   summarise(date = max(date), .groups = "drop")
2825
2826 # construct a table with nice fields names
2827 table <-
2828   inner_join(last_dates,
2829              Rt_data,
2830              by = c("area_type", "country", "province", "district", "type", "date")) %>%
2831   select(-count) %>%
2832   inner_join(
2833     inner_join(
2834       inner_join(
2835         last_dates,
2836         Rt_data,
2837         by = c("area_type", "country", "province", "district", "type", "date")
2838       ) %>%
2839         select(area_type, country, province, district, type, date_start, date_end),
2840       Rt_data %>% select(area_type, country, province, district, type, date, count),
2841       by = c("area_type", "country", "province", "district", "type")
```

Output

5.1.11 Reproduction Number

Below current (last weekly) effective reproduction number estimates are tabulated for South Africa and by province.

Estimated Effective Reproduction Number for South Africa

	Type	Count (Per Day)	Week Ending	Reproduction Number [95% Confidence Interval]
South Africa	cases	4,789	2022-04-27	1.54 [1.42 - 1.69]
South Africa	hospital_admissions	216	2022-04-28	0.97 [0.86 - 1.09]

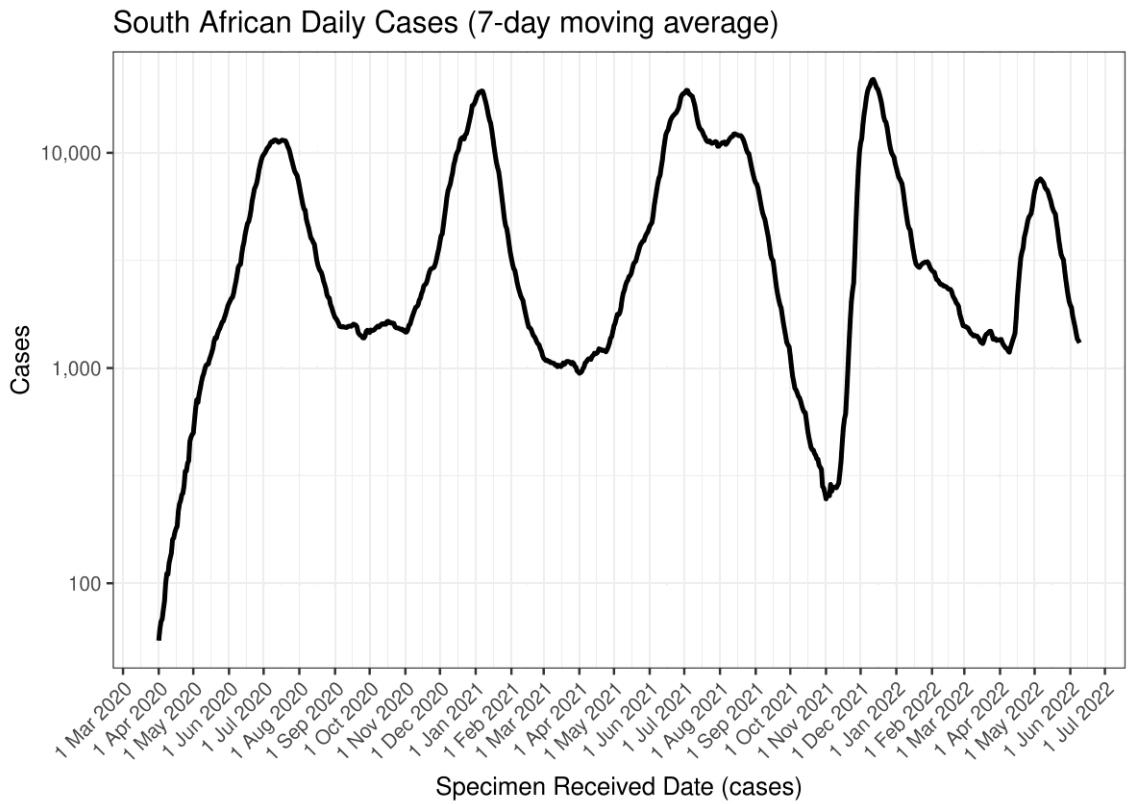
Estimated Effective Reproduction Number by Province

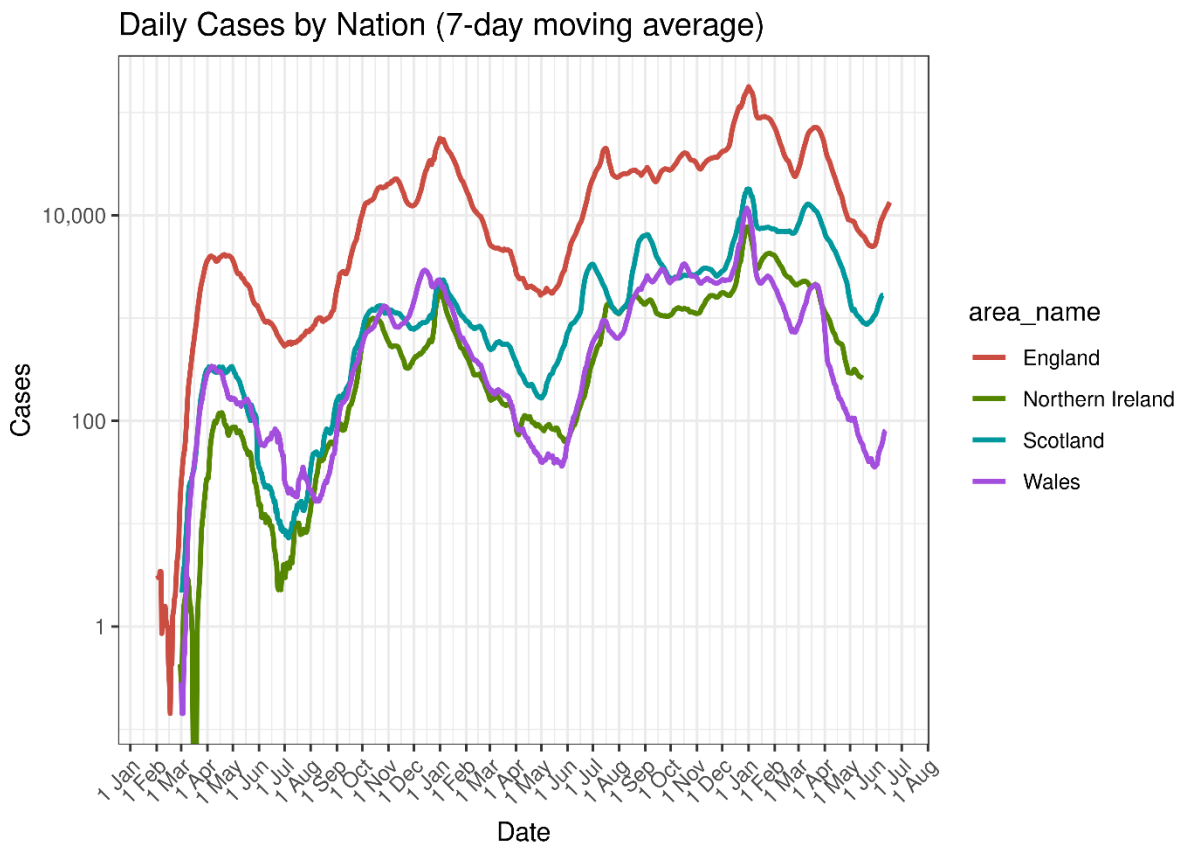
Province	Type	Count (Per Day)	Week Ending	Reproduction Number [95% Confidence Interval]
Eastern Cape	cases	167	2022-04-27	1.27 [1.17 - 1.39]
Eastern Cape	hospital_admissions	6	2022-04-28	1.09 [0.79 - 1.44]
Free State	cases	173	2022-04-27	1.93 [1.72 - 2.14]
Free State	hospital_admissions	9	2022-04-28	1.18 [0.90 - 1.50]
Gauteng	cases	2,346	2022-04-27	1.52 [1.41 - 1.64]
Gauteng	hospital_admissions	85	2022-04-28	0.74 [0.59 - 0.92]
KwaZulu-Natal	cases	1,102	2022-04-27	1.63 [1.47 - 1.81]
KwaZulu-Natal	hospital_admissions	58	2022-04-28	1.41 [1.24 - 1.61]
Limpopo	cases	55	2022-04-27	2.00 [1.70 - 2.32]
Limpopo	hospital_admissions	4	2022-04-28	1.32 [0.86 - 1.89]
Mpumalanga	cases	120	2022-04-27	1.63 [1.47 - 1.81]
Mpumalanga	hospital_admissions	7	2022-04-28	1.40 [1.03 - 1.84]
North West	cases	111	2022-04-27	1.74 [1.57 - 1.92]
North West	hospital_admissions	9	2022-04-28	0.70 [0.43 - 1.09]

Other automation enablers

- Reproducible
  - Environment
  - Same data, same result
- Code contains all steps
  - No manual steps

Results – Cases



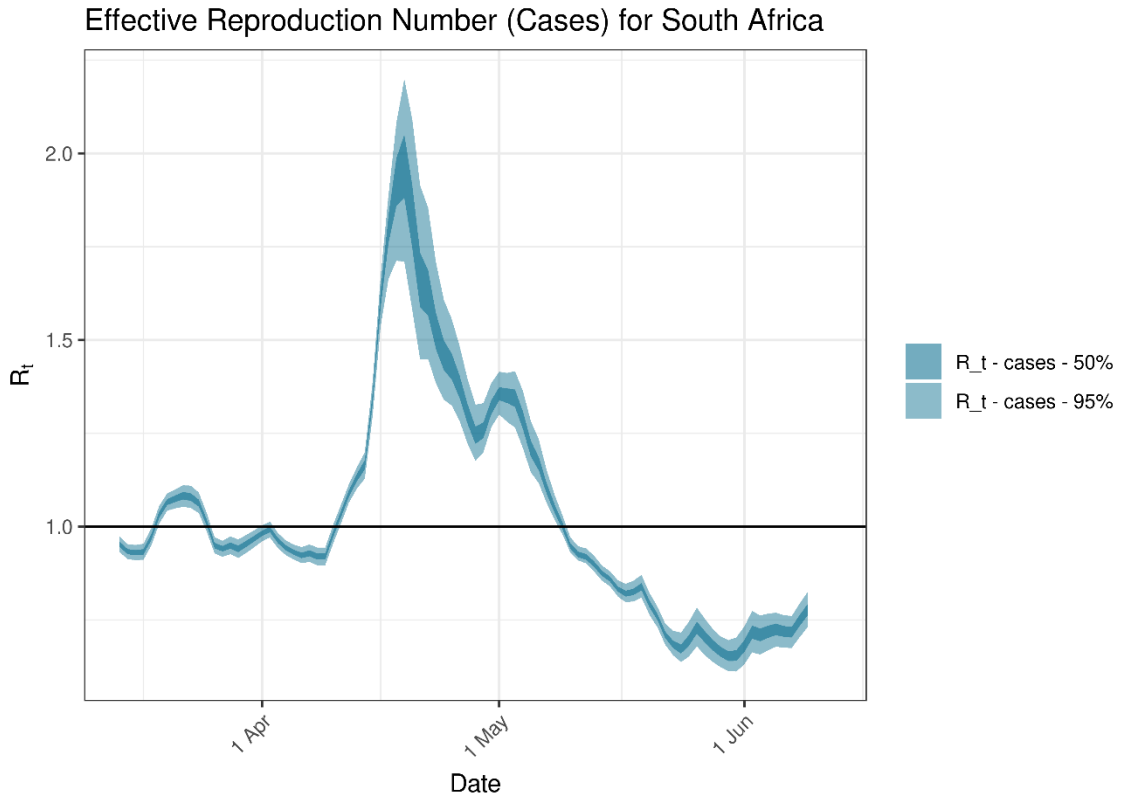


https://unsupervised.online/static/covid-19/estimating_r_za.html

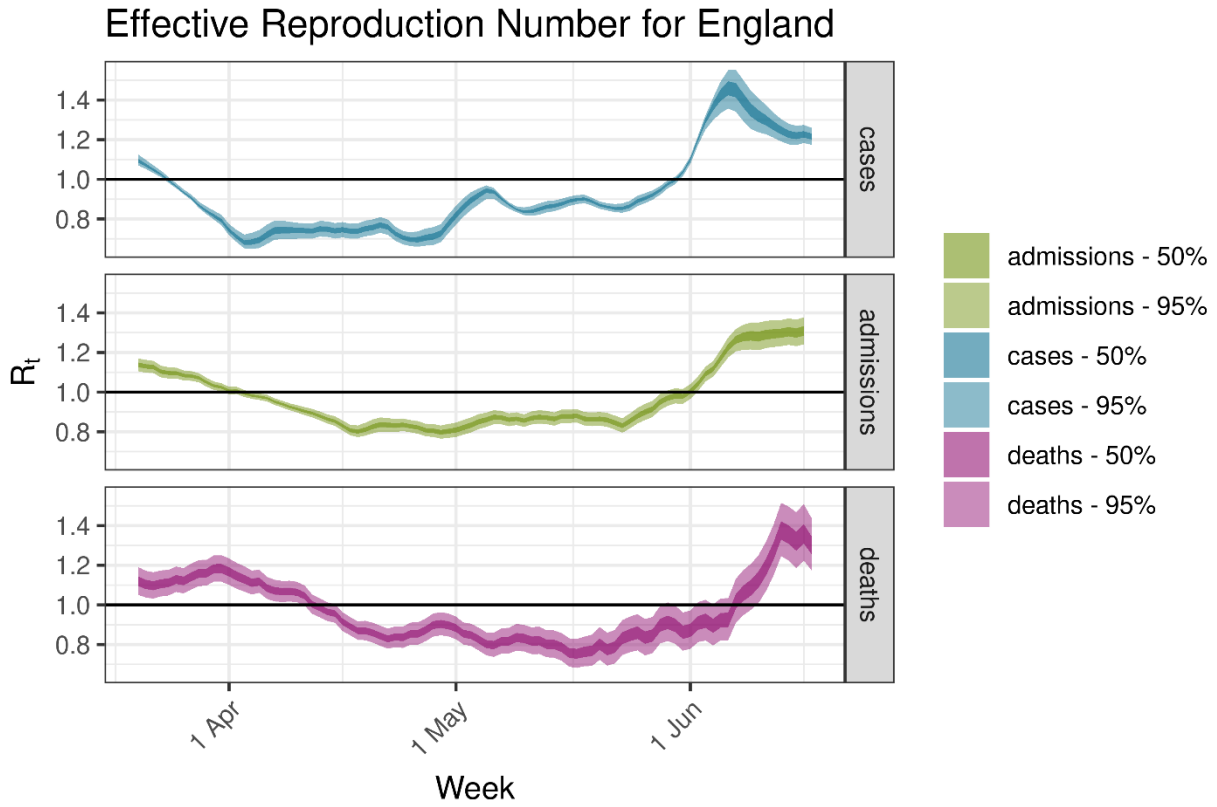
https://unsupervised.online/static/covid-19/estimating_r_uk.html

and Faculty of Actuaries

Reproduction number



https://unsupervised.online/static/covid-19/estimating_r_za.html



https://unsupervised.online/static/covid-19/estimating_r_uk.html

Institute and Faculty of Actuaries

South African Crude Ratios Per Wave

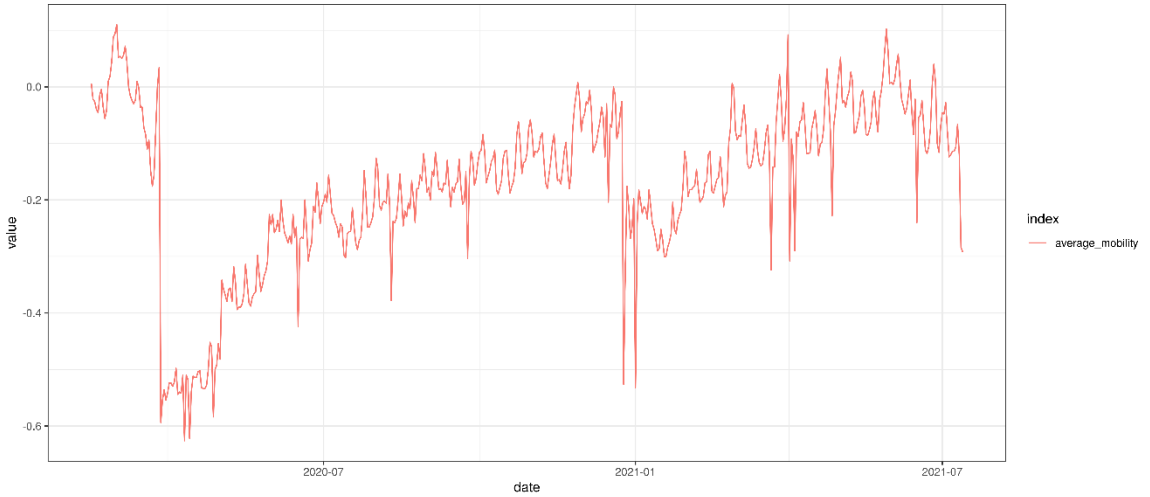
Wave	Case Admission Ratio	Case Fatality Ratio	Case Excess Deaths Ratio	Hospital Fatality Ratio	Death Reporting Ratio
Wave 1	10.2%	1.87%	7.01%	18.3%	26.7%
Wave 2 (Beta)	20.3%	4.40%	12.36%	21.7%	35.6%
Wave 3 (Delta)	13.4%	3.10%	8.36%	23.1%	37.0%
Wave 4 (Omicron)	9.8%	0.95%	4.45%	9.7%	21.4%
Wave 5 (BA.4/BA.5)	9.3%	0.72%	5.05%	7.7%	14.2%

https://unsupervised.online/static/covid-19/estimating_r_za.html

Institute and Faculty of Actuaries

Modelling

- Bayesian Hierarchical Model to calibrate model parameters based on observed death data and prior assumptions
- Reproductive number is linked to mobility data as well as mask wearing laws
- Reproductive number generates infections
- Population weighted IFRs to model deaths from infections
- Single combined model for all provinces
- Allows for uncertainty
  - Prior assumptions
  - Updated posteriour distributions
  - Projections allow for parameter uncertainty
- No allowance for vaccines.



Online model:

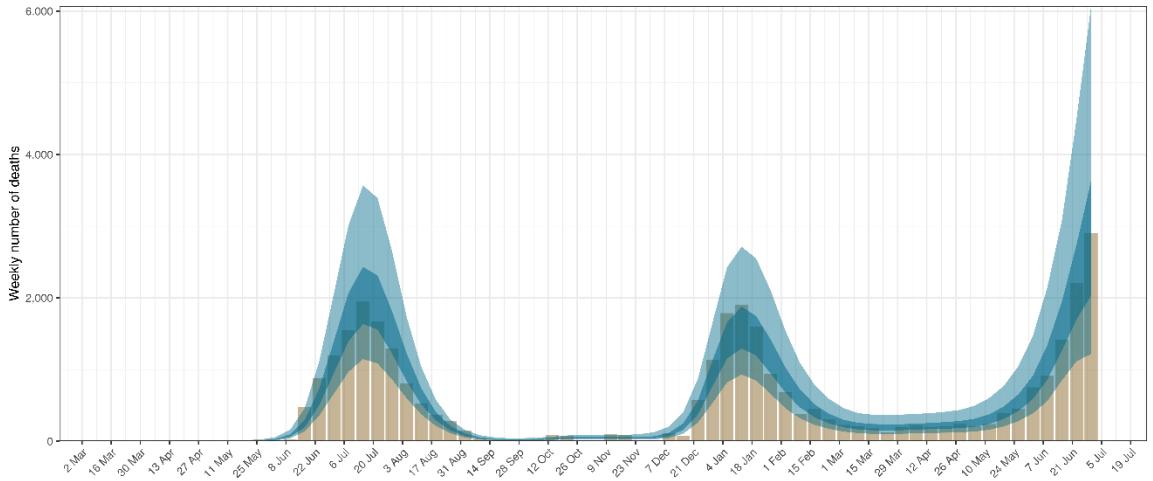
- South Africa by Province

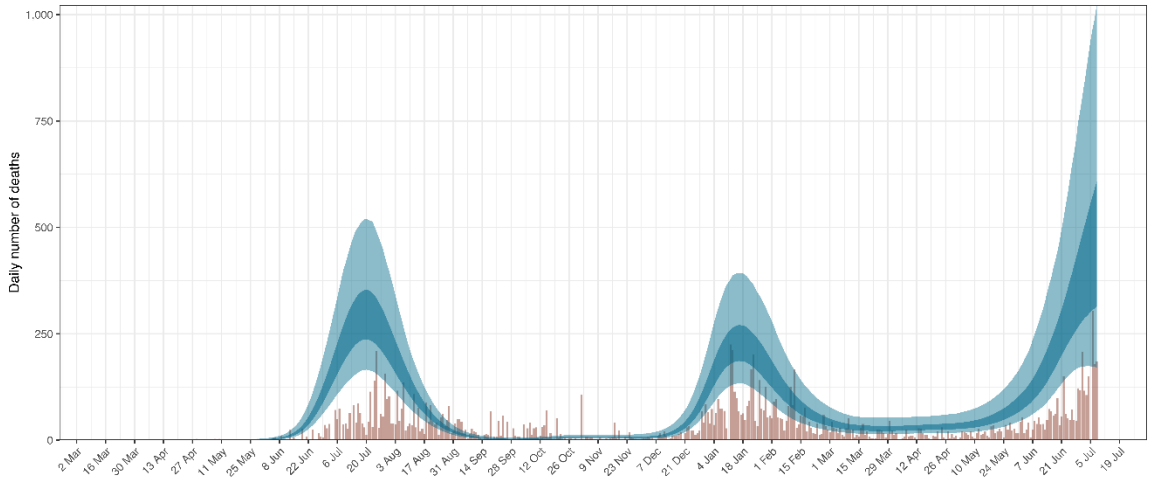
Institute and Faculty of Actuaries

Calibration to Excess Deaths

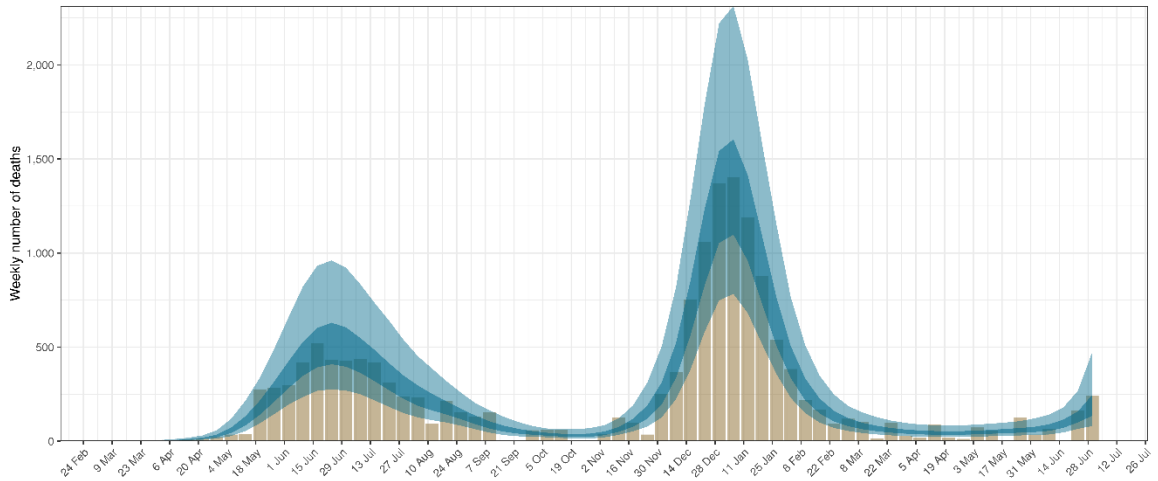
Reported deaths shown for reference

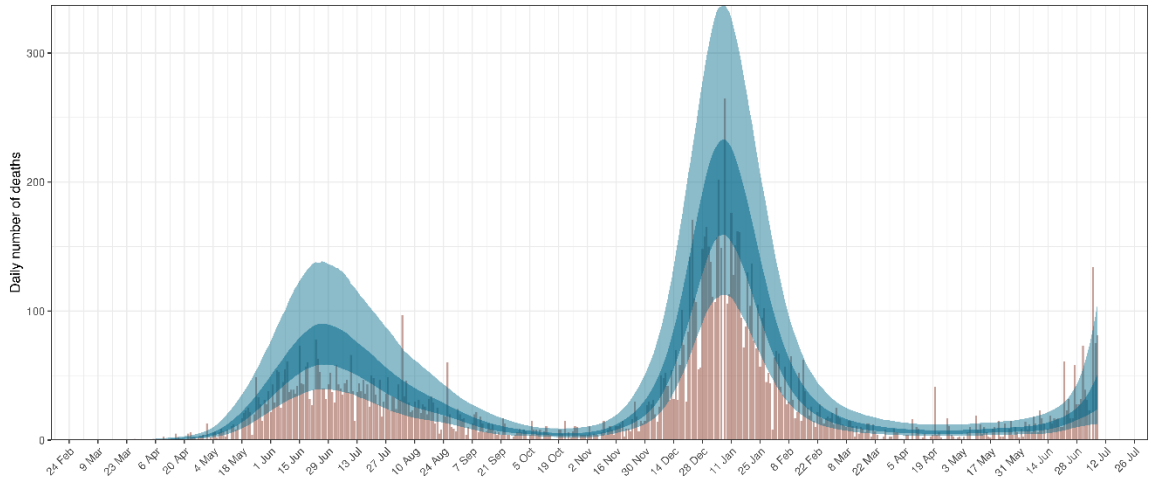
Gauteng



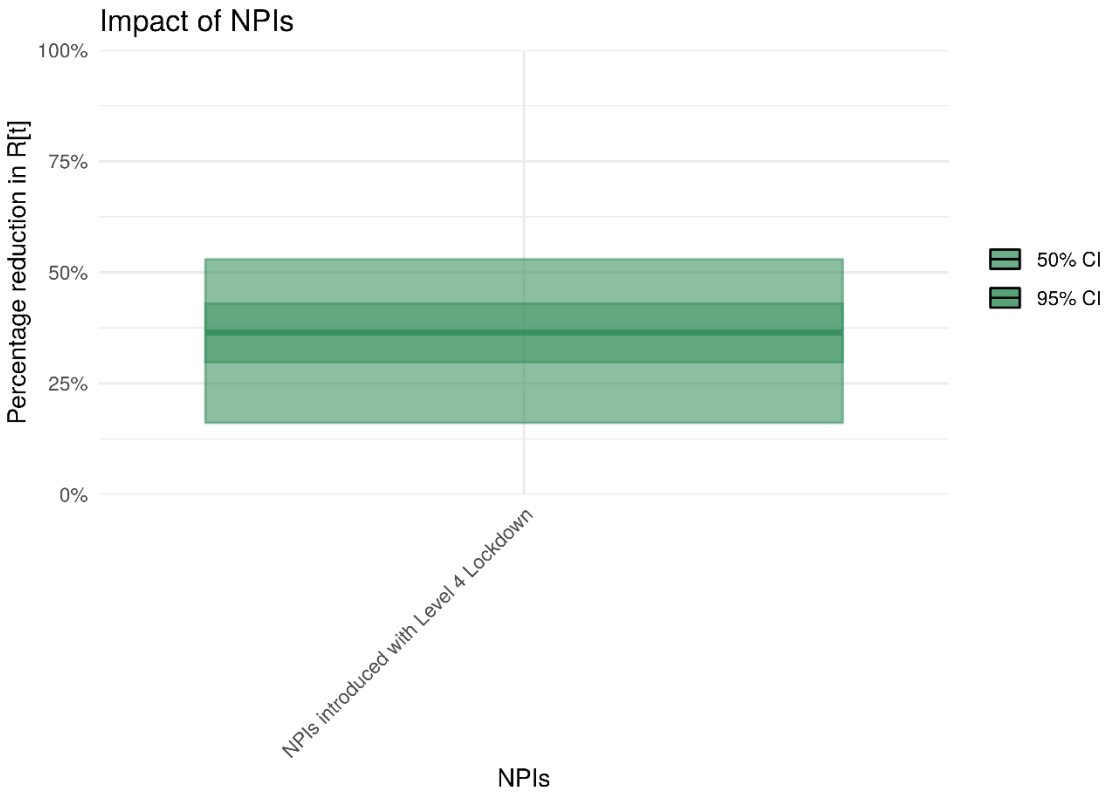


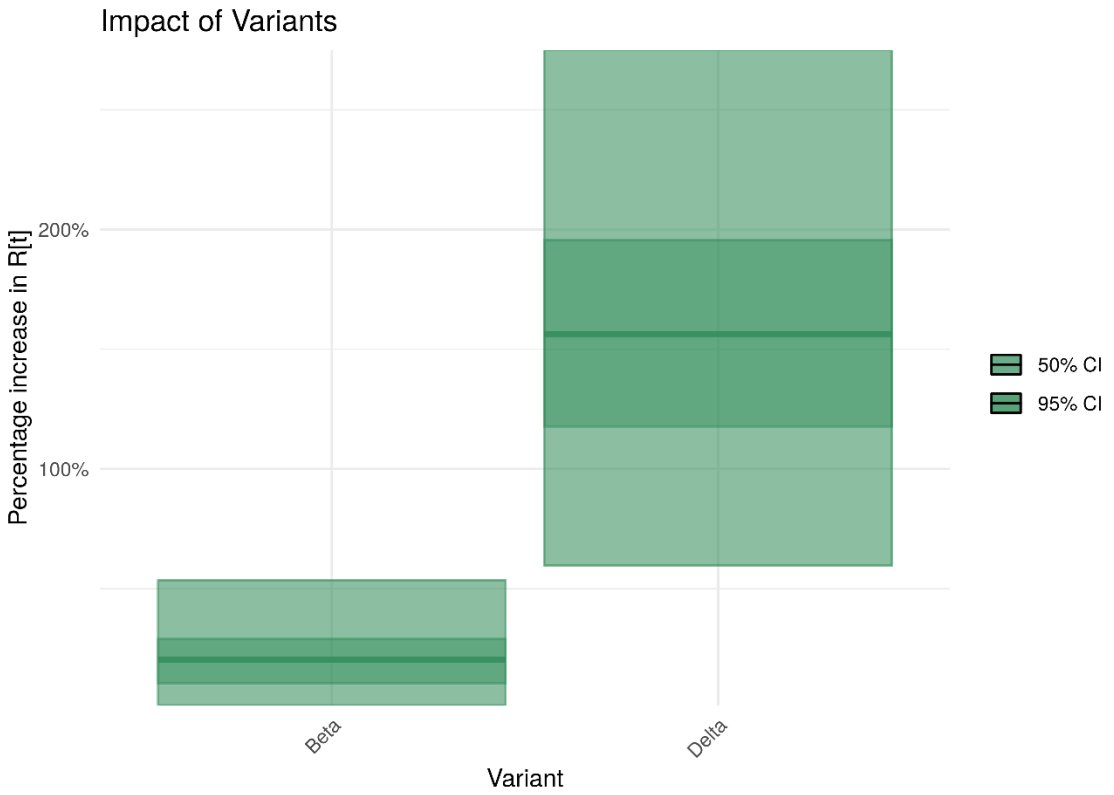
Western Cape





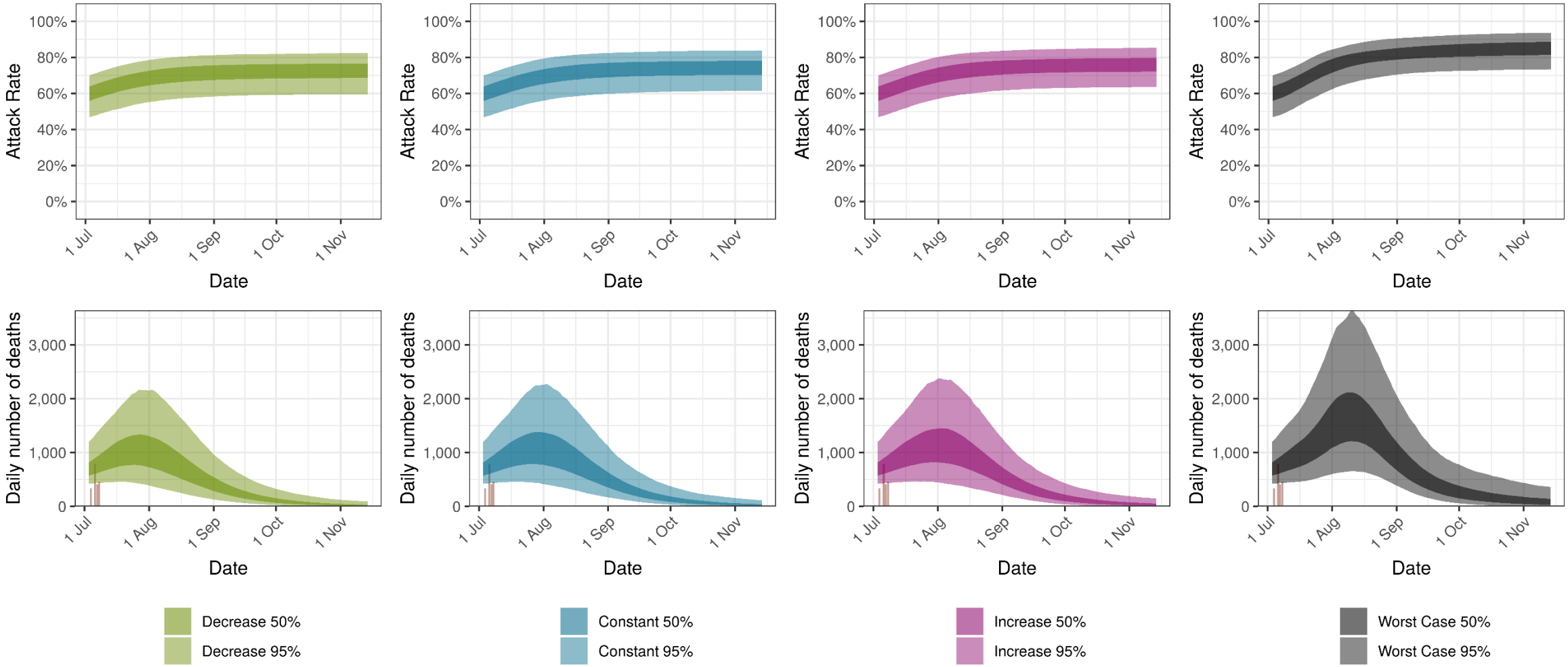
Parameters and uncertainty





Institute and Faculty of Actuaries

Projections – South Africa



Predictions

"Nowcast" estimates as of 8 July 2021

Province	Attack Rate	Cumulative Deaths
South Africa	61.6% [48.6%-72.0%]	173 450 [155 890 – 192 740]

"Worst-case" predictions to December 2021

Scenario	Attack Rate	Cumulative Deaths
Worst Case	85.0% [73.6%-93.7%]	273 152 [221 026 – 355 246]
No Change	74.0% [61.6%-83.9%]	237 368 [198 504 – 293 123]

Institute and Faculty of Actuaries

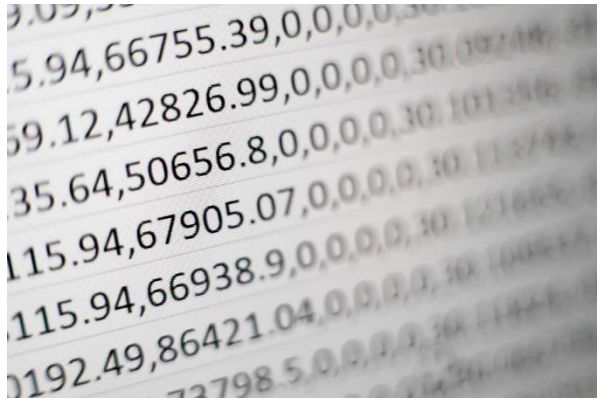
Thinking past COVID-19?

Actuaries need to handle uncertainty in many contexts

Prior Views

- Prior studies
- Judgement
- Population data
- Emerging risks

Data



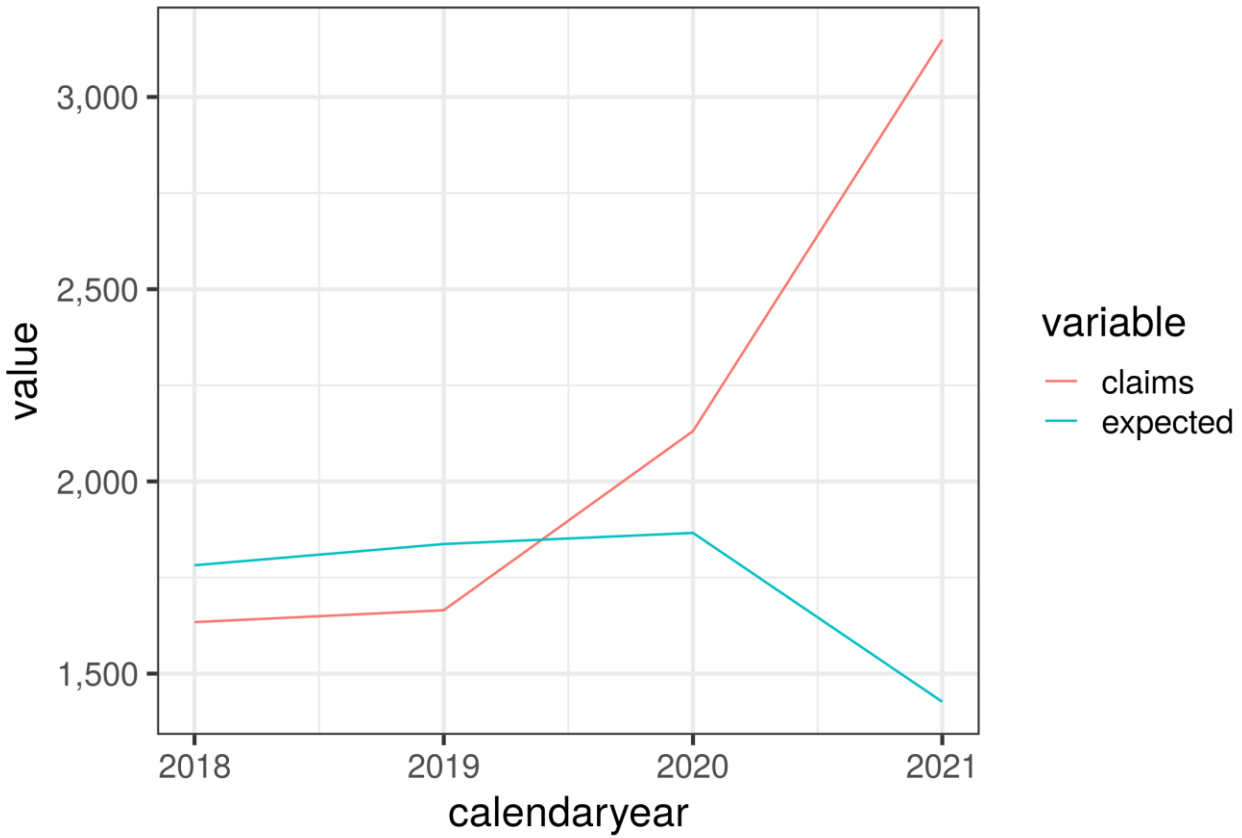
Posterior

- Updated distributions
  - New mean
  - Updated uncertainty
- Reflecting combination
- Very complex models

Institute and Faculty of Actuaries

Insured Experience 2020-2021

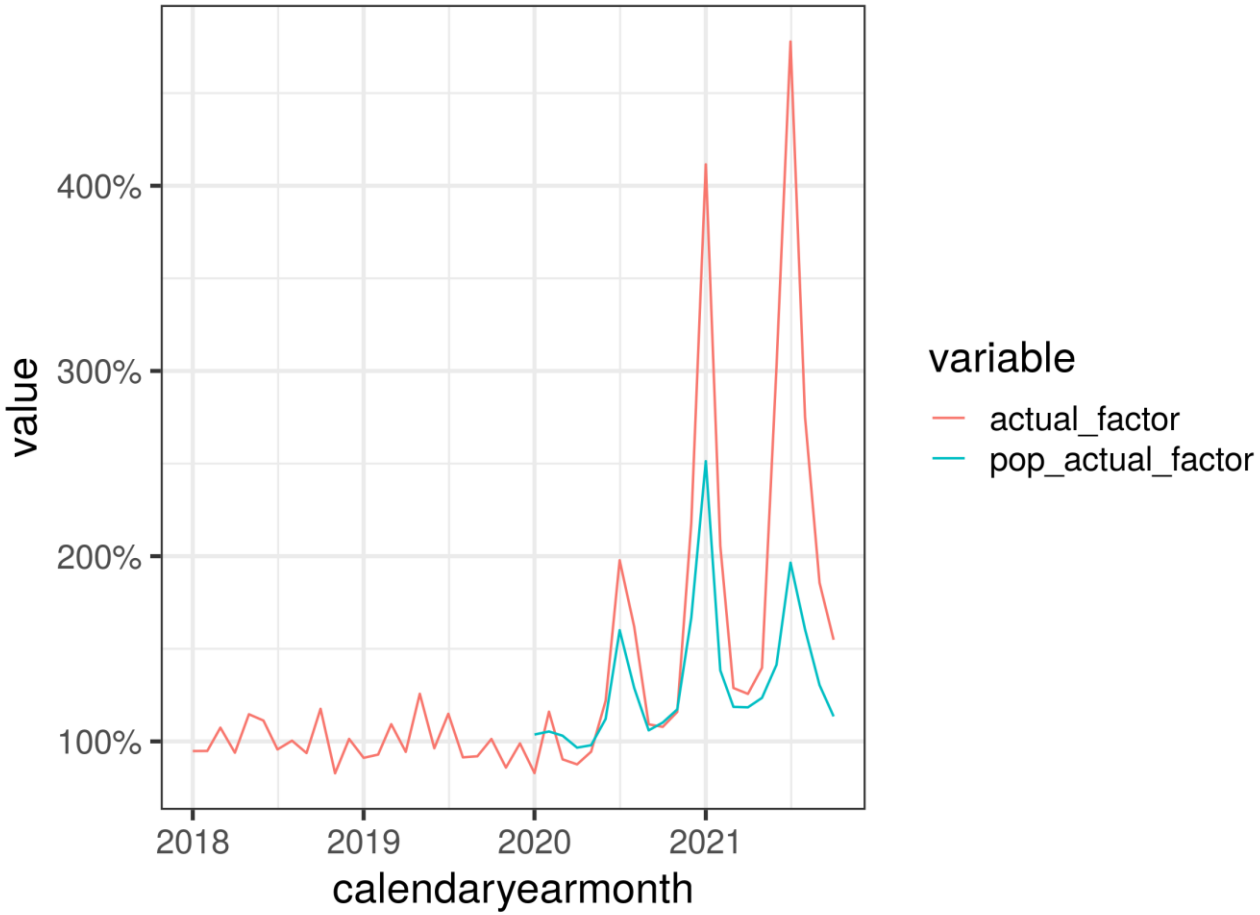
- Claims well over expected
- Understand patterns in experience
- Underlying experience?



Institute and Faculty of Actuaries

Step 1: Break-down exposure

- Monthly exposure and claims
- Insured experience worse?
- Median age in population <25
- Insured much older.



Institute and Faculty of Actuaries

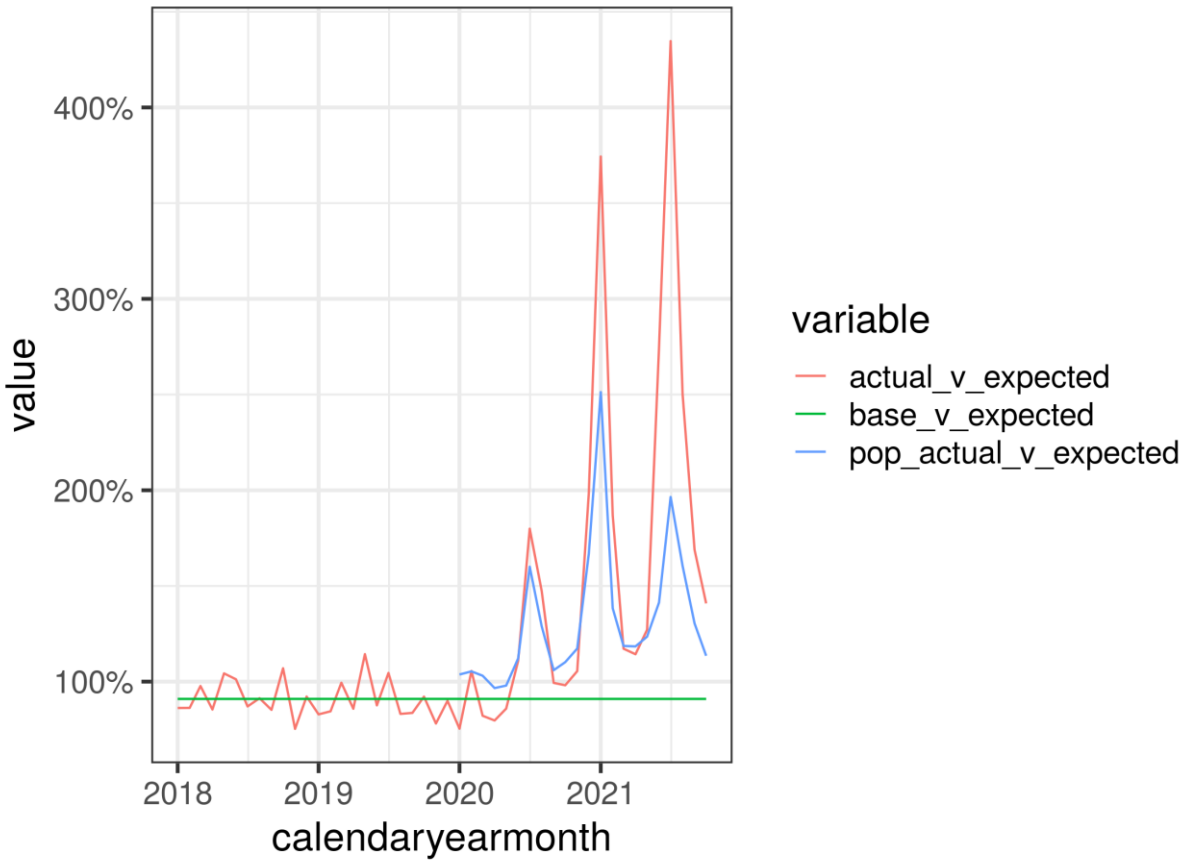
Step 2: Model

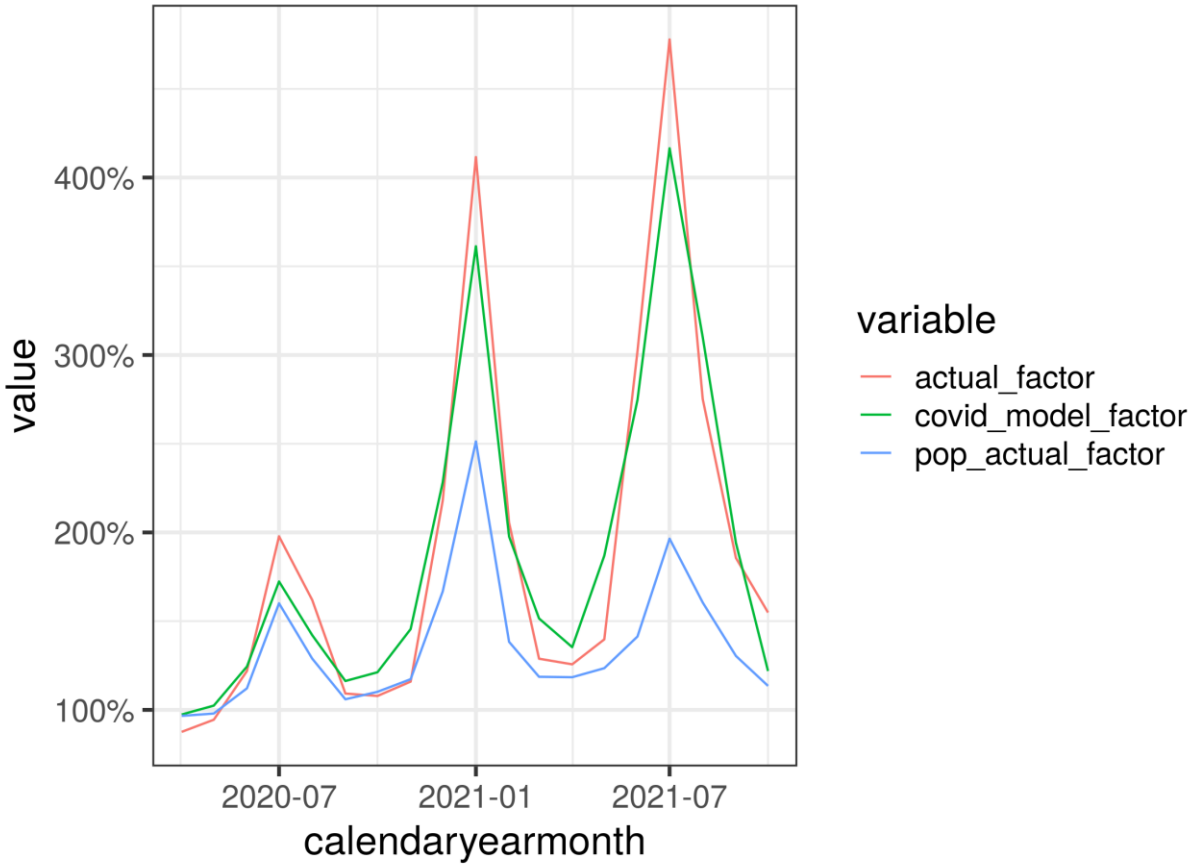
- Model structure

$$\log\left({}^{actual}/_{expected}\right) \sim \sum_i x_i\beta_i + x^{covid}\sum_i x'_i\beta'_i$$

- x^{covid} is an indicator variable (0 before April 2020, otherwise 1)
- Additionally, the second term contains shape adjustments on a monthly basis
  - Allows approximate matching of experience by month
  - Allows contains terms for age, gender, face bands etc
- In theory we can separate out the underlying experience $\sum_i x_i\beta_i$ from the COVID-19 experience $x^{covid}\sum_i x'_i\beta'_i$
- Penalised regression to select variables.

Modelling Results Overview





Institute and Faculty of Actuaries

Results – Two ways to measure excess

Relative (%)

- Actual

$$\frac{actual}{expected \cdot e^{\sum_i x_i \beta_i}}$$

- Modelled

$$\frac{expected \cdot e^{\sum_i x_i \beta_i + x^{covid} \sum_i x'_i \beta'_i}}{expected \cdot e^{\sum_i x_i \beta_i}}$$

Excess mortality as percentage of the underlying

Additional Excess

- Actual

$$\frac{actual \ - expected \cdot e^{\sum_i x_i \beta_i}}{exposure}$$

- Modelled

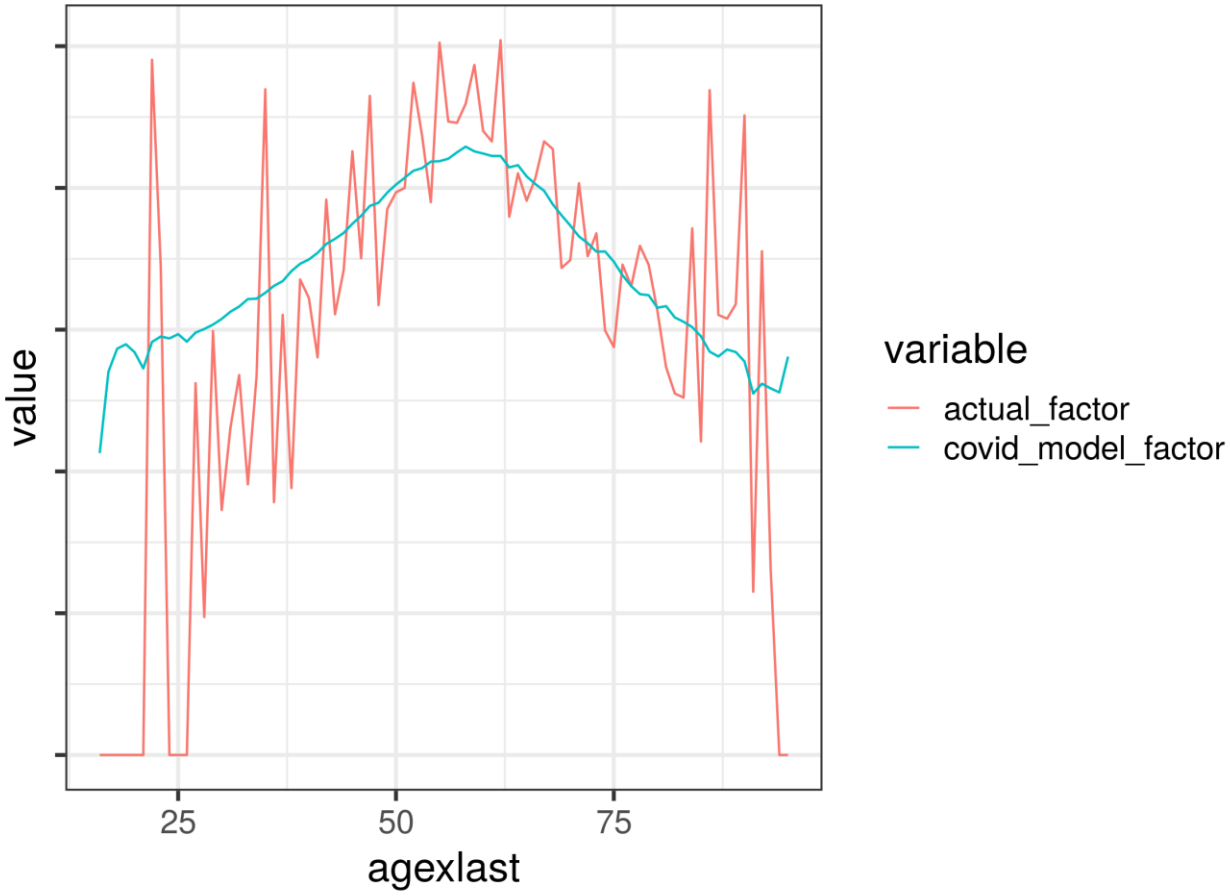
$$\frac{expected \cdot e^{\sum_i x_i \beta_i + x^{covid} \sum_i x'_i \beta'_i} - expected \cdot e^{\sum_i x_i \beta_i}}{exposure}$$

Additional central mortality rate per annum.

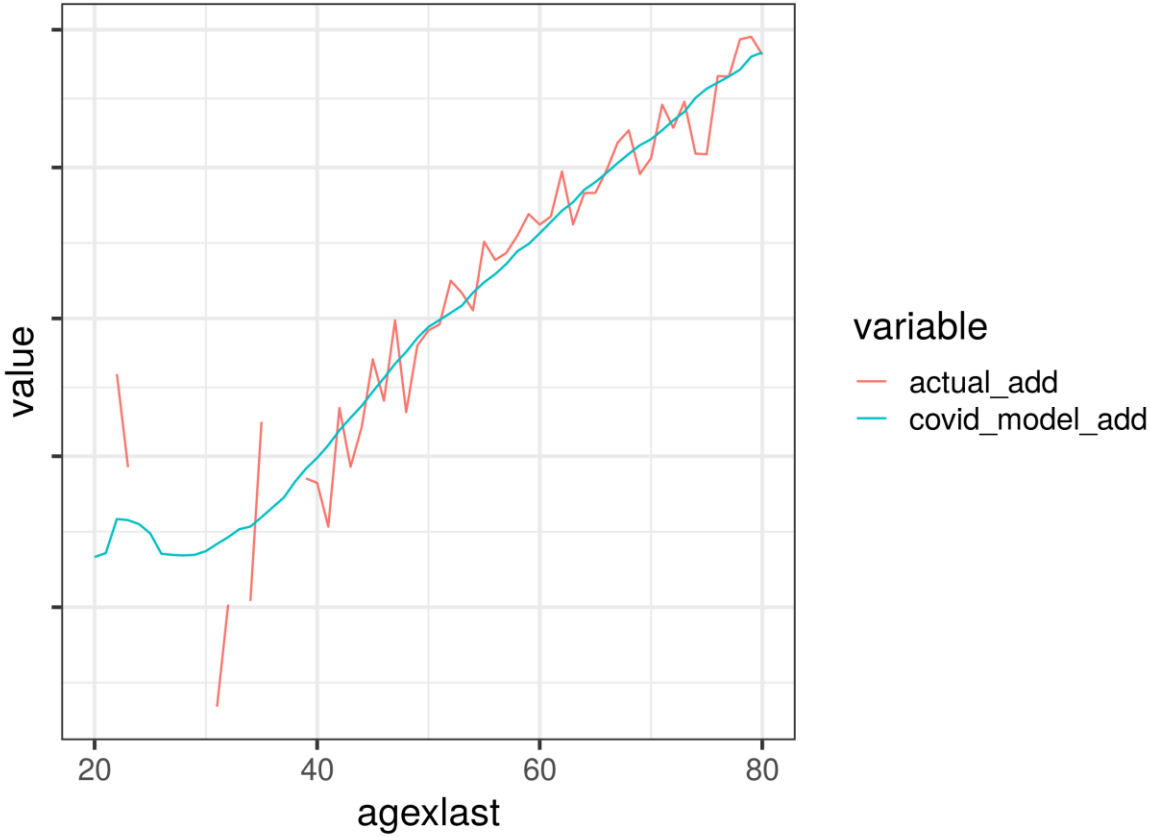
Institute and Faculty of Actuaries

By Ages

Excess Mortality (Factor)



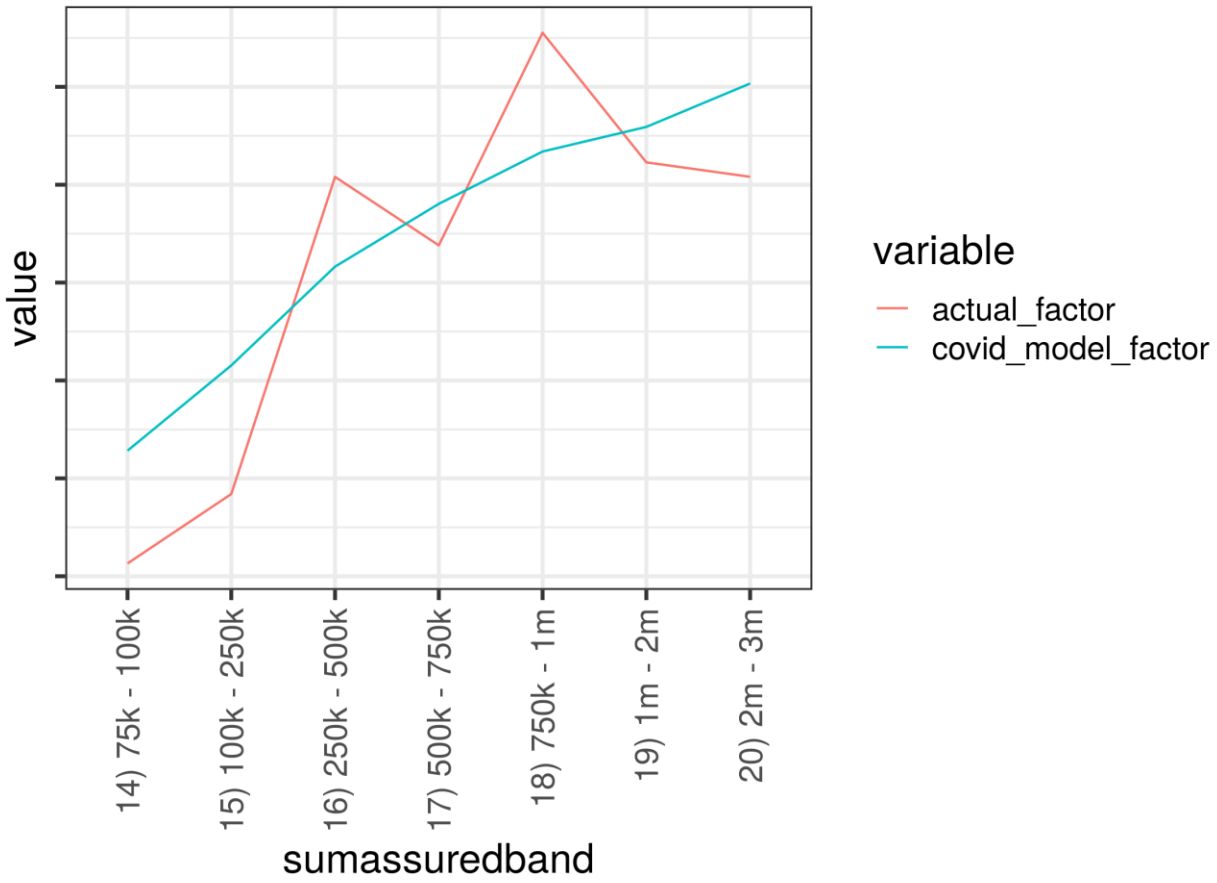
Excess Mortality (Additional)



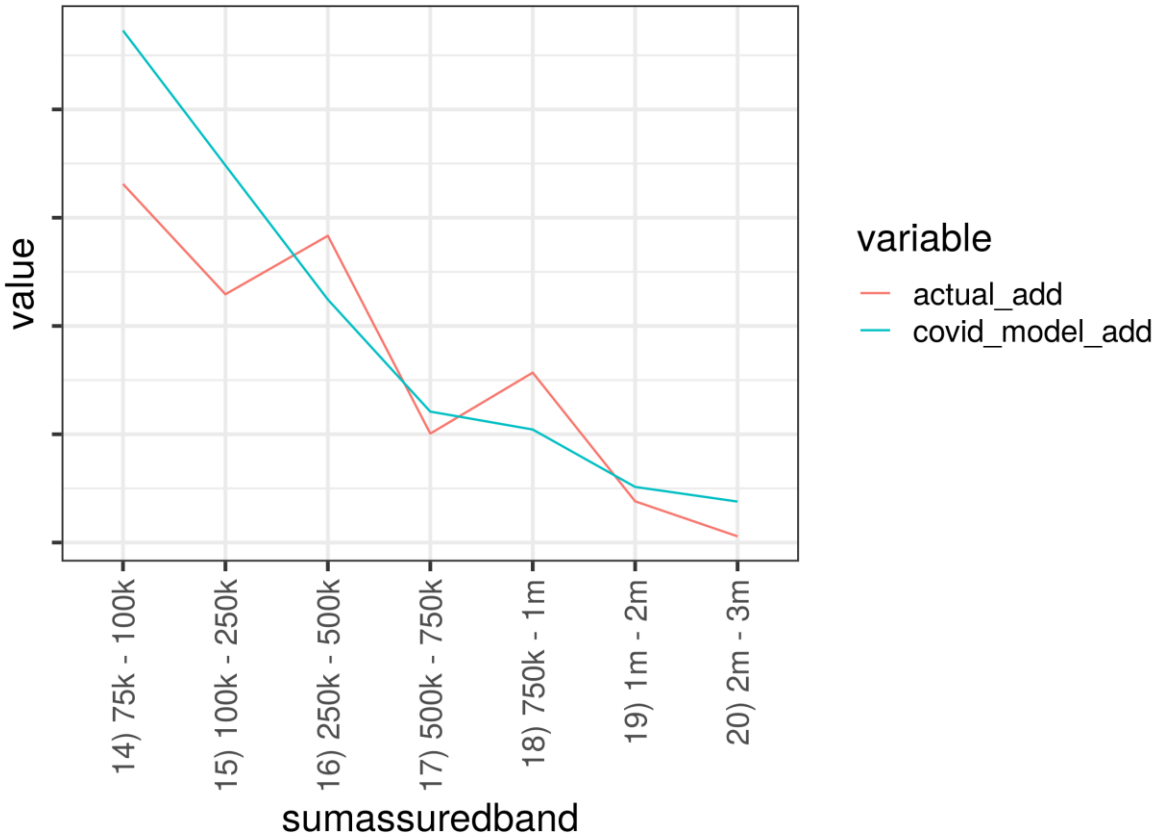
Institute and Faculty of Actuaries

Sum Assured Bands

Excess Mortality (Factor)



Excess Mortality (Additional)



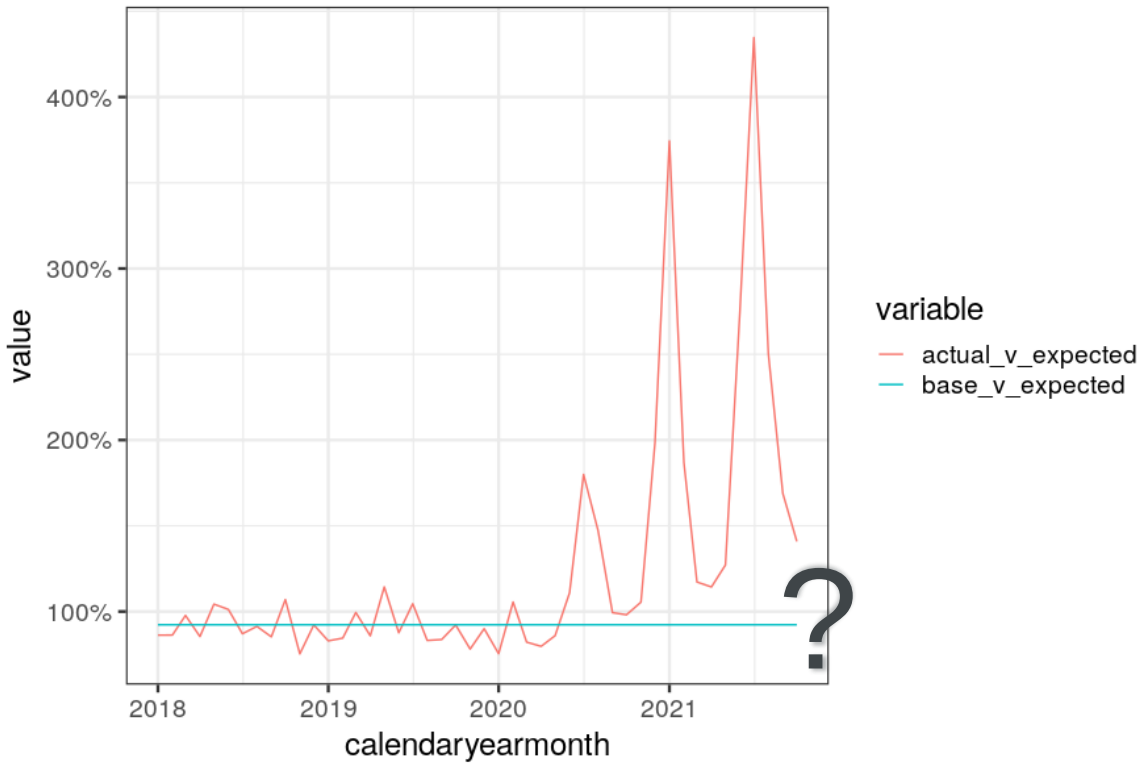
Institute and Faculty of Actuaries

Other insights from experience

- Later waves had relatively worse experience at higher sums assured
- Later waves experience was relatively worse at younger age bands
- Standard vs. non-standard experience similar in relative terms

Problem Solved?

- A bridge too far?
- Some “post-COVID” experience would be useful
- Extreme example
- Helps understand underlying patterns
- Informed decision making
  - Requiring judgement
  - Allowance for outlook
- Monitoring.



Institute and Faculty of Actuaries

Advancing Analytics with COVID-19

- “Standing on the shoulders of giants”
  - Open data
  - Open packages
  - Collaboration gets things done
- Code tracking

- Automation is key
- Uncertainty
  - Parameter
  - Systemic
- Parameter uncertainty
- Judgement required

Institute and Faculty of Actuaries

Questions

Comments

Expressions of individual views by members of the Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.

Institute and Faculty of Actuaries

Thank You

Louis Rossouw

LRossouw@GenRe.com

Rob Kaner

Robert.Kaner@GenRe.com

Institute and Faculty of Actuaries