Symposium on Mortality and Longevity

# Mortality shocks in annuity portfolios

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# Overview

1. Covid-19
2. Annuity portfolios
3. Non-parametric approach
4. Reporting delays
5. Parametric approach
6. Conclusions

# 1 Covid-19

# 1 Covid-19

- Covid-19 is the disease caused by the novel SARS-CoV-2 virus[†].
- Covid-19 can be fatal…

[†]The Novel Coronavirus Pneumonia Emergency Response Epidemiology Team [2020].

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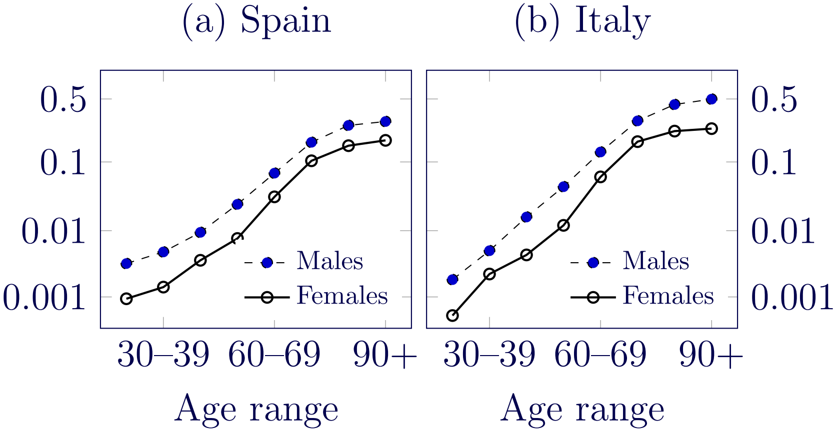
Mortality rate by age for confirmed covid-19 infection‡. Logit scale.




‡Own calculations using data from CCAES [2020] and ISS [2020].

# 1 Covid-19

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- Covid-19 is the disease caused by the novel SARS-CoV-2 virus[†].
- Covid-19 can be fatal…

  …and its arrival was obvious in national mortality statistics…

[†]The Novel Coronavirus Pneumonia Emergency Response Epidemiology Team [2020].

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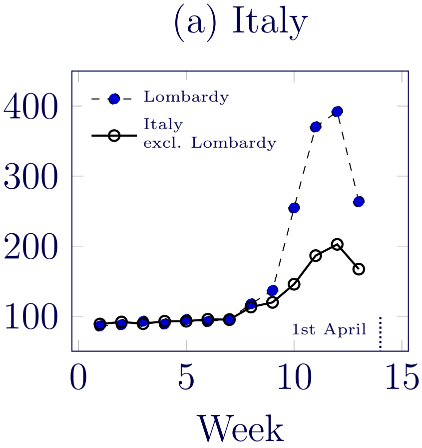
Deaths in early 2020 as percentage of average in 2015–2019♣.




♣ Source: own calculations using data from Istat [2020] and ONS [2020].

# 1 Covid-19

Covid-19 mortality shock was:

- Intense.
- Short-term (measured in weeks).
- Very localised.

How might it impact annuity portfolios?

# 2 Annuity portfolios

# 2 Annuitant experience data

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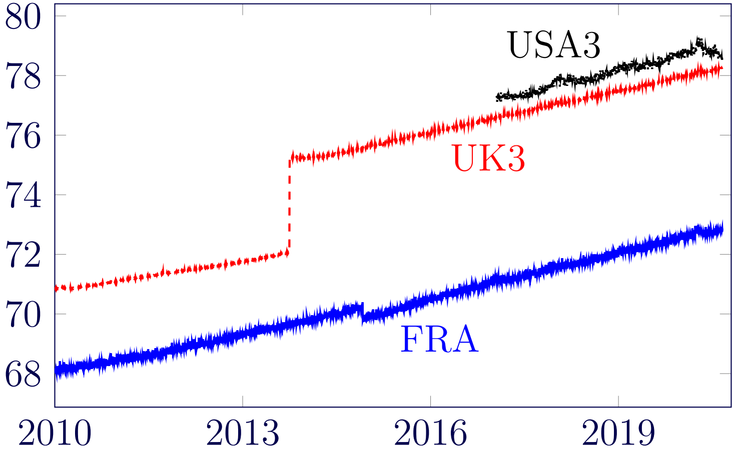
| Portfolio | Cumulative deaths | In-force 1st April 2020 |
|---|---|---|
| FRA | 47,026 | 251,330 |
| UK3 | 109,878 | 146,269 |
| USA3 | 145,153 | 723,762 |

Data extracted in September 2020. Source: Richards [2021].

# 2 Data

Average age of in-force annuitants.




Source: Richards [2021].

# 3 Non-parametric approach

# 3 Definitions

- $\mu_x$ is the mortality hazard at age $x$.
- $\Lambda_x(t) = \int_0^t \mu_{x+s} ds$ is the integrated hazard.
- Normally the above are defined with respect to age, $x$.
- What if we define things with respect to time, $y$?

# 3 Definitions

- $\{y + t_i\}$ is the set of distinct dates of death,
- $d_{y+t_i}$ is the number of deaths at date $y + t_i$, and
- $l_{y+t_i^-}$ is the number of lives immediately before $y + t_i$.

# 3 Nelson-Aalen estimator

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$$\hat{\Lambda}_{y,t} = \sum_{t_i \leq t} \frac{d_{y+t_i}}{l_{y+t_i^-}} \tag{1}$$

$\hat{\Lambda}_{y,t}$ estimates the integrated hazard.

See

https://www.longevitas.co.uk/site/informationmatrix/visualisingcovid19inexperiencedata.html.

# 3 FRA portfolio, $\hat{\Lambda}_{2010,t}$

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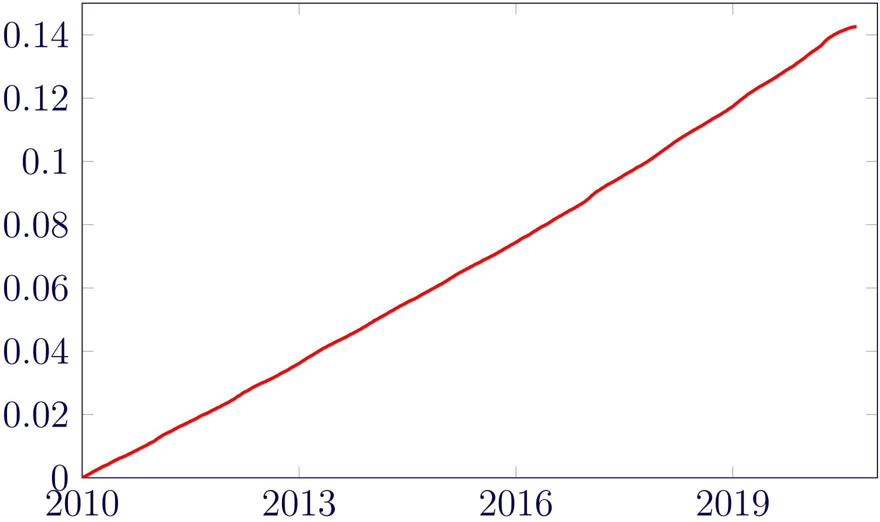

# 3 Non-parametric estimator

- $\hat{\Lambda}_y$ is near-linear (and rather dull).
- What about taking first differences?

# 3 Non-parametric estimator

First central difference around $\hat{\Lambda}_{y,t}$:

$$\hat{\mu}_{y+t} = \frac{\hat{\Lambda}_{y,t+c/2} - \hat{\Lambda}_{y,t-c/2}}{c} \tag{2}$$

where $c > 0$ is the bandwidth parameter.

See

https://www.longevitas.co.uk/site/informationmatrix/visualisingcovid19inexperiencedata.html.

# 3 FRA, $\hat{\mu}_{2010,t}$, $c = 0.5$

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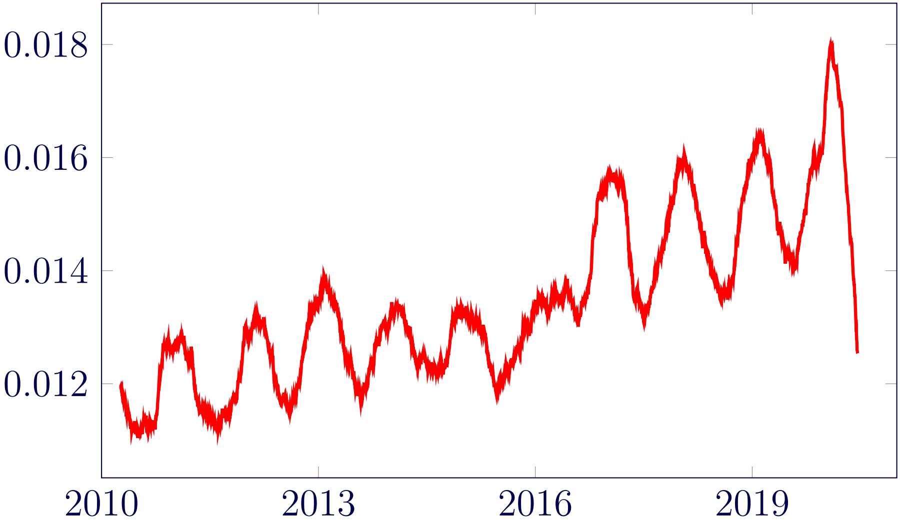

# 3 Non-parametric estimator



- $\hat{\Lambda}_y$ is near-linear (and rather dull).
- However, $\hat{\mu}_y$ reveals rich detail of seasonal patterns.
- Can $\hat{\mu}_y$ reveal the covid-19 shock?

# 3 FRA $\hat{\mu}_{2015+t}$, $c = 0.2$

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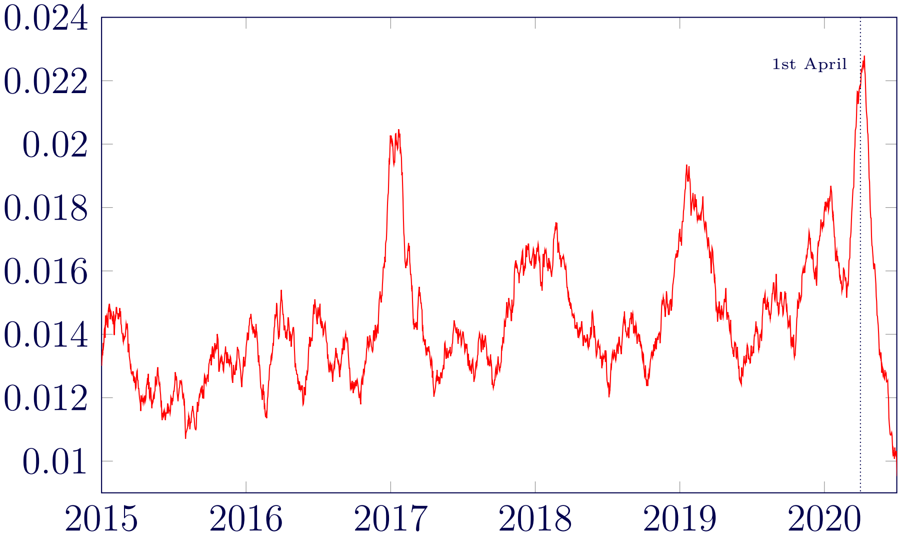

# 3 UK3 $\hat{\mu}_{2015+t}$, $c = 0.2$

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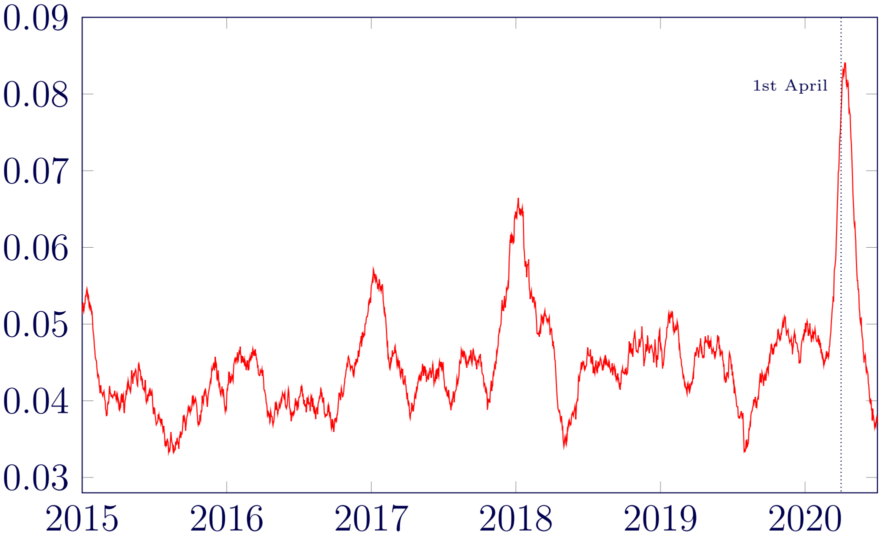

# 3 USA3 $\hat{\mu}_{2017+t}$, $c = 0.2$

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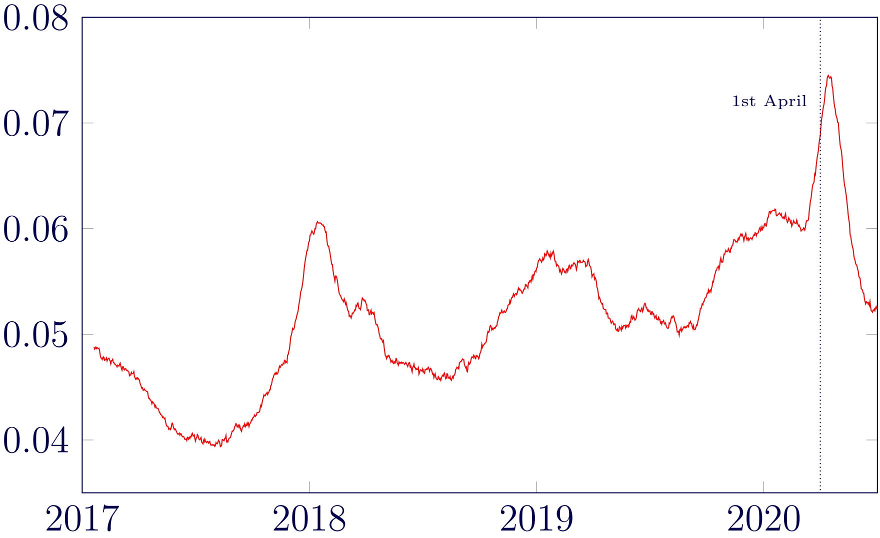

# 3 Non-parametric estimator

Covid-19 shock hit French, UK and US annuity portfolios at the same time, peaking in April 2020.

# 3 Data privacy

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- Only need:
    - Date of annuity commencement,
    - Date of annuity cessation, and
    - Nature of cessation (death, withdrawal etc).
- No personal data required.
- GDPR, CCPA and PIPEDA do not apply!

# 3 Non-parametric estimator

Advantages:

- Reveals seasonal variation.
- Reveals mortality shocks.
- Requires no personal data (GDPR-, CCPA- and PIPEDA-safe).

# 3 Non-parametric estimator

Drawbacks:

- Smoothing understates shock.
- Can't separate shock from seasonal effect.
- Doesn't allow for key risk factors like age.
- Not defined for most recent $c/2$ years.
- Affected by reporting delays.

# 4 Reporting delays

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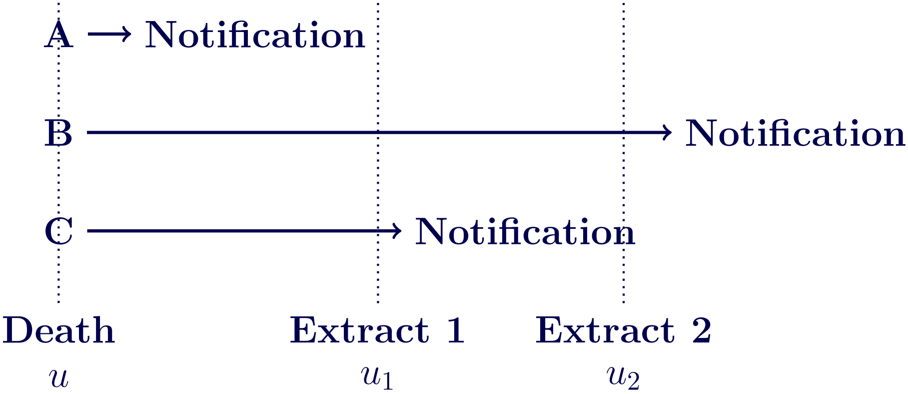
Consider same week for UK3 using two extracts:

| Date | June 2020 extract: In-force | June 2020 extract: Deaths | Sept. 2020 extract: In-force | Sept. 2020 extract: Deaths |
|---|---|---|---|---|
| 2020-06-11 | 145,166 | 6 | 144,934 | 18 |
| 2020-06-12 | 145,163 | 3 | 144,920 | 16 |
| 2020-06-13 | 145,168 | 9 | 144,918 | 14 |
| 2020-06-14 | 145,159 | 1 | 144,909 | 7 |
| 2020-06-15 | 145,162 | 3 | 144,906 | 15 |
| 2020-06-16 | n/a | n/a | 144,898 | 8 |
| 2020-06-17 | 145,168 | 3 | 144,902 | 29 |

# 4 Reporting delays

- Assume we have two extracts at time $u_1$ and $u_2$ $(u_1 < u_2)$.
- Assume a death occurs at time $u < u_1$.
- There are three possible reporting types...

# 4 Reporting delays



# 4 Reporting delays



- Type A deaths reported by time of first extract.
- Type B deaths reported after second extract. Unknown to us!
- Type C deaths reported between extracts.

# 4 Reporting delays



- Types B and C are occurred-but-not-reported (OBNR).
- Similar term IBNR (incurred-but-not-reported) refers to general insurance claims.
- The distinction was made by Lawless [1994].

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Calculate ratio of $\hat{\mu}_y$ estimates using two extracts:

$$R(s, u_1, u_2) = \frac{\hat{\mu}_{u_1-s} \text{ using extract at time } u_1}{\hat{\mu}_{u_1-s} \text{ using extract at time } u_2} \tag{3}$$

OBNR impact negligible when $R$ is close to 1.

# 4 Impact of reporting delays

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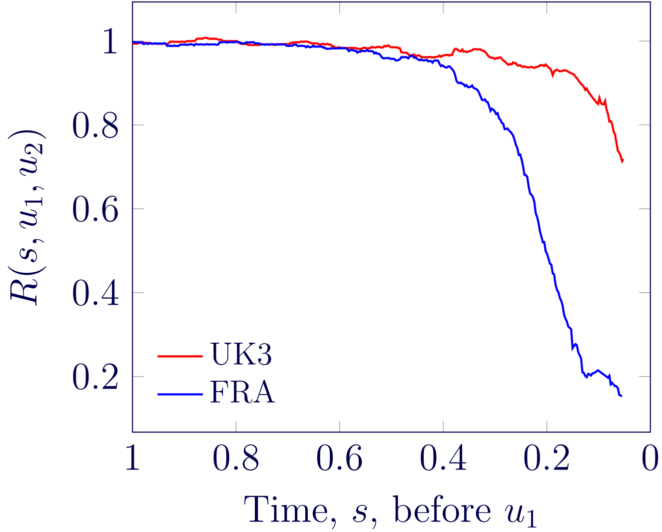

# 4 Reporting delays (OBNR)

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- OBNR affects most recent mortality estimates.
- Most impact within 0.25 years of extract.
- Minimal impact 0.75 or more years before extract.

See https://www.longevitas.co.uk/site/informationmatrix/reportingdelays.html.

# 5 Parametric approach

# 5 Reporting delays

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Look again at the ratio measuring the impact of OBNR:

$$R(s, u_1, u_2) = \frac{\hat{\mu}_{u_1-s} \text{ using extract at time } u_1}{\hat{\mu}_{u_1-s} \text{ using extract at time } u_2} \qquad (4)$$

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We can re-word this as follows:

$$\rho = \frac{\text{OBNR} - \text{affected } \hat{\mu}_y}{\text{Underlying } \hat{\mu}_y} \tag{5}$$

# 5 Reporting delays

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We can re-arrange as follows:

$$\text{OBNR-affected } \hat{\mu}_y = \text{Underlying } \hat{\mu}_y \times \rho$$

# 5 Parametric approach

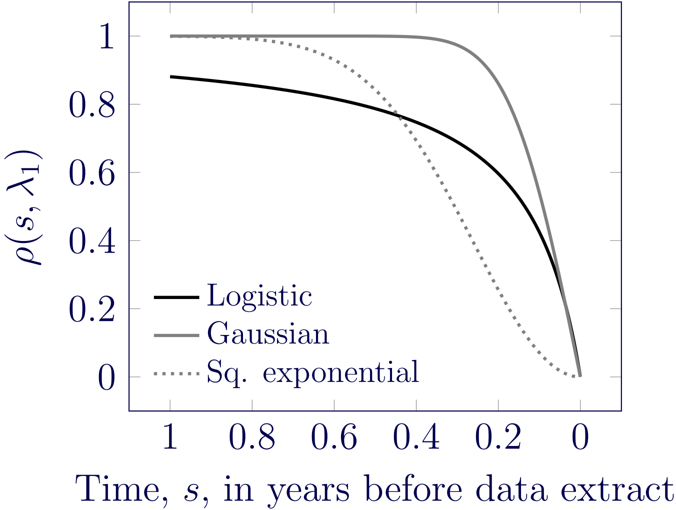


Model for OBNR-affected mortality, $\mu_{x,y}^{OBNR}$:

$$\mu_{x,y}^{OBNR} = \mu_{x,y}^{*}\rho(u_1 - y, \lambda_1) \tag{6}$$

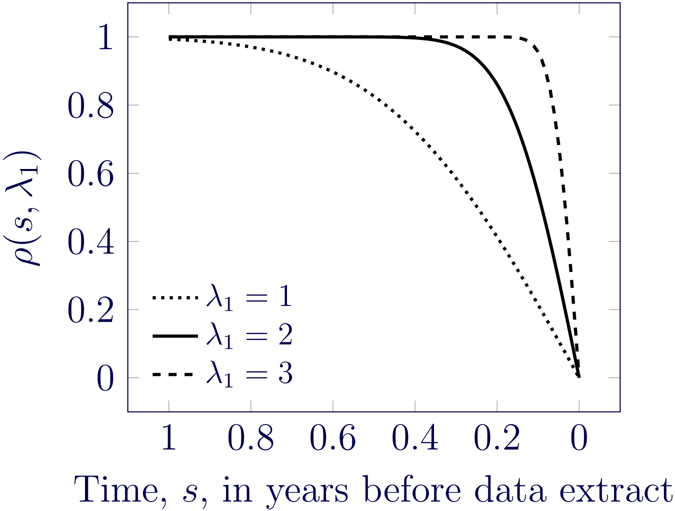
- $\mu_{x,y}^{OBNR}$ is reported mortality,
- $\mu_{x,y}^{*}$ is actual mortality experienced,
- $\rho(s, \lambda_1)$ is scaling factor for OBNR, and
- $\lambda_1$ is the OBNR decay parameter.

# 5 Options for $\rho(s, \lambda_1 = 2)$




Details of these and other functions in Richards [2021].

Gaussian OBNR function:



# 5 Forecasting

- Can we use a model at time $u_1$ to predict the unreported deaths by time $u_2$?
- Can we use the OBNR function to adjust for unreported deaths?

# 5 Forecasting OBNR

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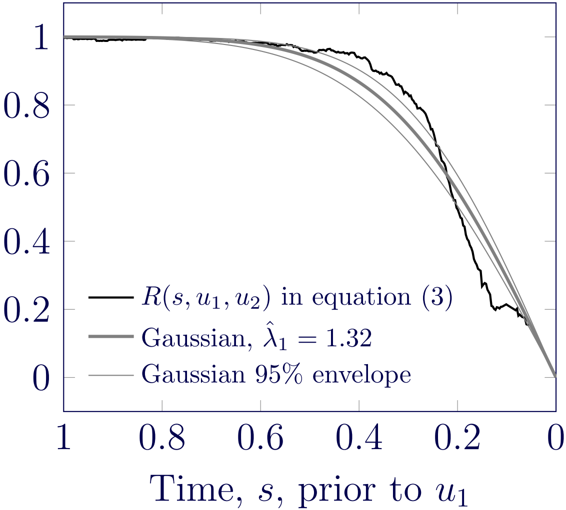
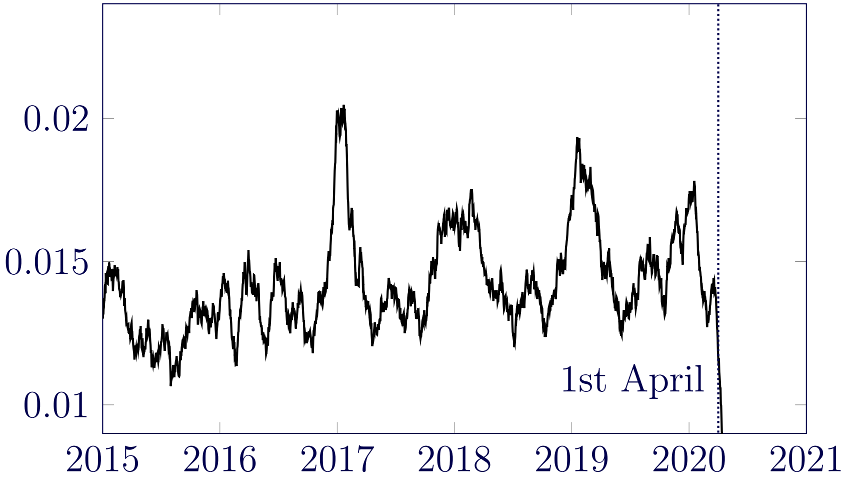


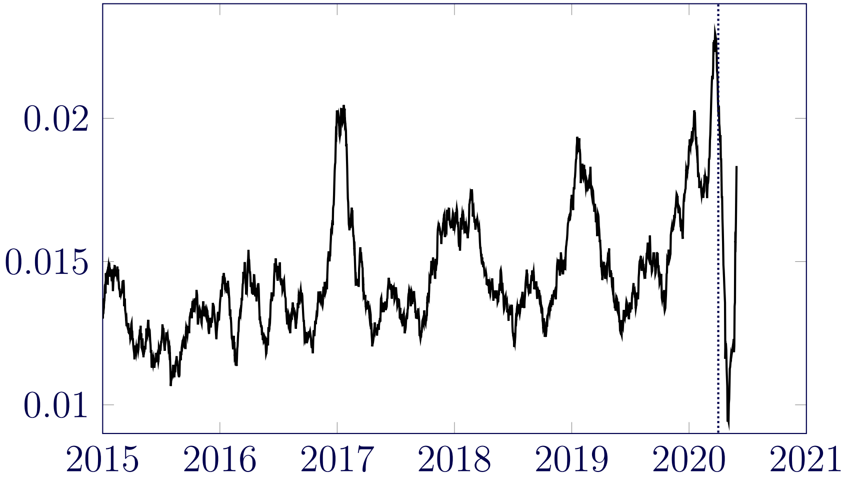
# 5 Adjusting for OBNR

FRA, June extract:



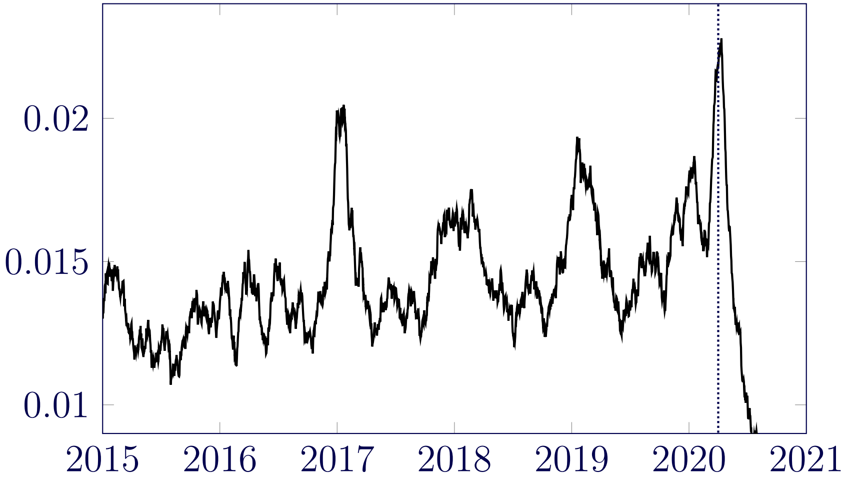
# 5 Adjusting for OBNR

FRA, June extract with Gaussian OBNR adjustment:



# 5 Adjusting for OBNR

FRA, September extract:



# 6 Conclusions

# 6 Conclusions — I

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- Covid-19 shock detectable in annuity portfolios.
- Shock peaked in April 2020 in France, UK and USA.
- Non-parametric methods are privacy-safe.

# 6 Conclusions — II

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- Reporting delays affect most recent experience.
- However, parametric models can allow for delays. . .

  . . . and provide forecasts of unreported deaths.

# References I

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ISS. Epidemia COVID-19 Aggiornamento nazionale 16 giugno 2020 — ore 11:00. Technical report, Instituto Superiore de Sanità, 2020.

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ONS. Deaths registered weekly in England & Wales. Technical report, 2020. URL `https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/datasets/weeklyprovisionalfiguresondeathsregisteredinen`

S. J. Richards. Mortality shocks and reporting delays in portfolio data. *Longevitas Ltd*, 2021.

# References III

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The Novel Coronavirus Pneumonia Emergency Response Epidemiology Team. The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) — China, 2020. *China CDC Weekly*, 2:113, 2020. ISSN 2096-7071. URL `http://weekly.chinacdc.cn//article/id/e53946e2-c6c4-41e9-9a9b-fea8db1a8f51`.

More on longevity risk at www.longevitas.co.uk

# 7 Legal matters

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