IFoA webinar series on Covid-19

Mortality shocks in annuity portfolios

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Overview

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

1 Covid-19

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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...

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

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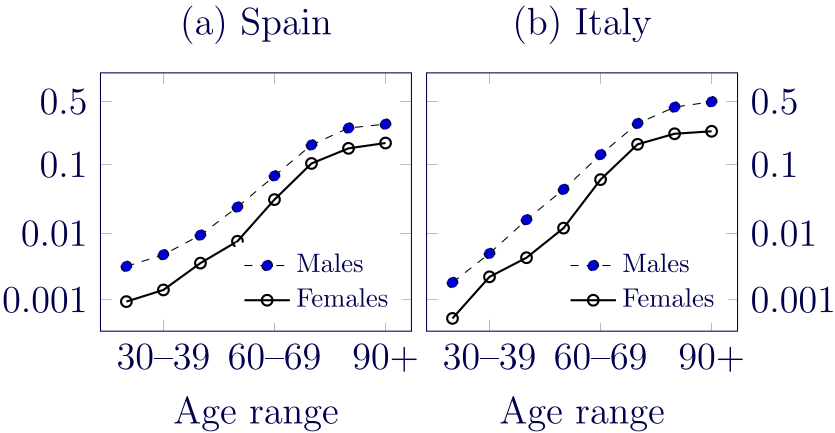
Mortality rate by age for confirmed covid-19 infection‡. Logit scale.



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

1 Covid-19

- 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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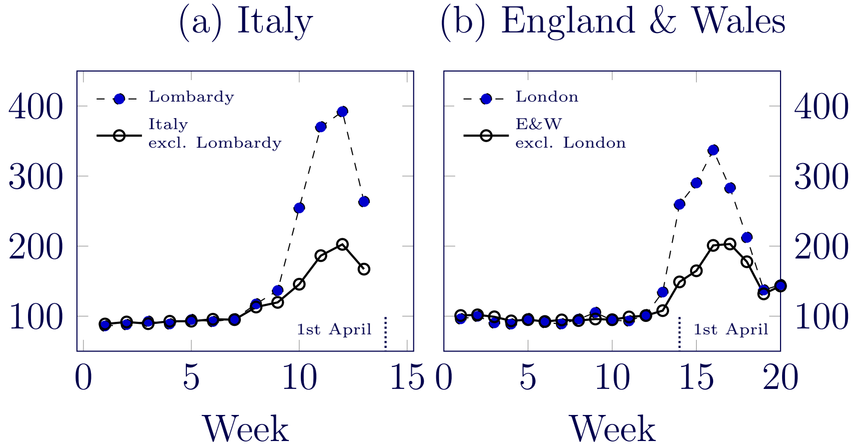
Deaths in early 2020 as percentage of average in 2015–2019[†].



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

1 Covid-19

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Covid-19 mortality shock was:

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

How might it impact annuity portfolios?

2 Annuity portfolios

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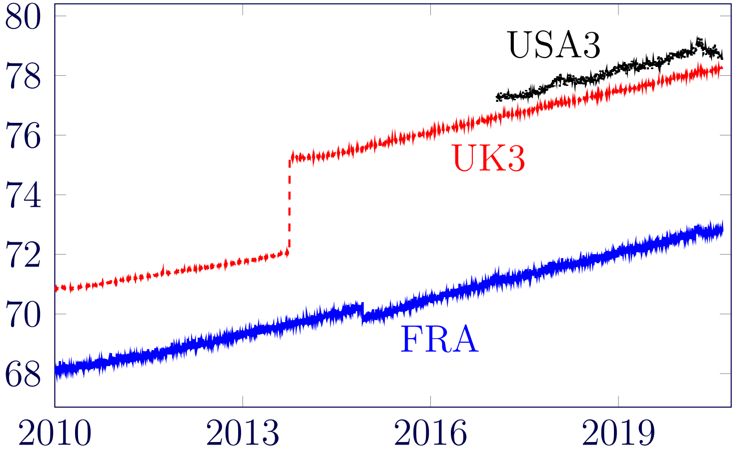
2 Annuitant experience data

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

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3 Definitions

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- μ_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

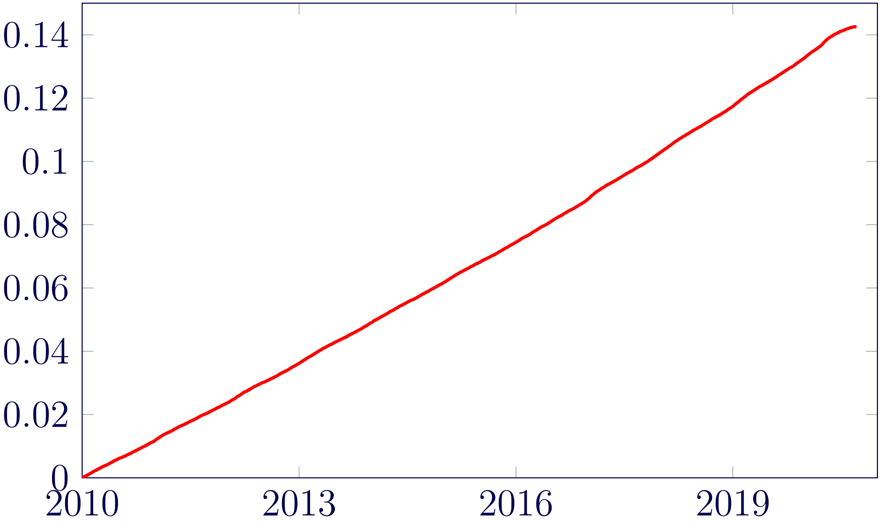
$$\hat{\Lambda}_{y,t} = \sum_{t_i \leq t} \frac{d_{y+t_i}}{l_{y+t_i^-}} \qquad (1)$$

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

See

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

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



3 Non-parametric estimator

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

3 Non-parametric estimator

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

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

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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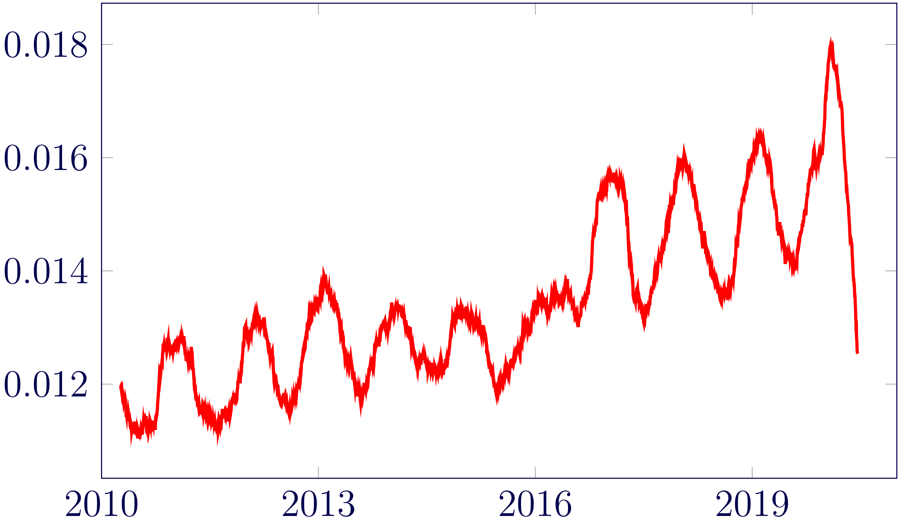

3 Non-parametric estimator

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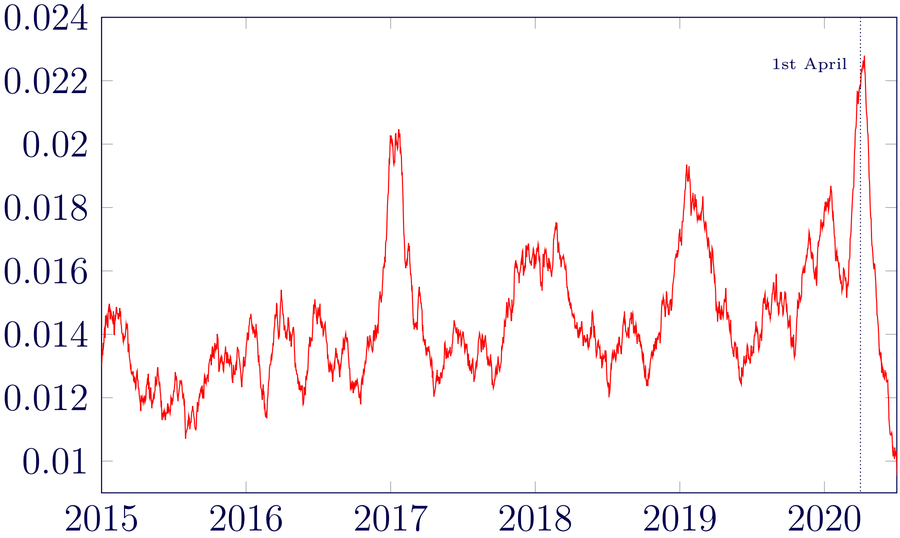
- $\hat{\Lambda}_y$ is near-linear (and rather dull).
- However, $\hat{\mu}_y$ reveals rich detail of seasonal patterns.
- Can $\hat{\mu}_y$ reveal the covid-19 shock?

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



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

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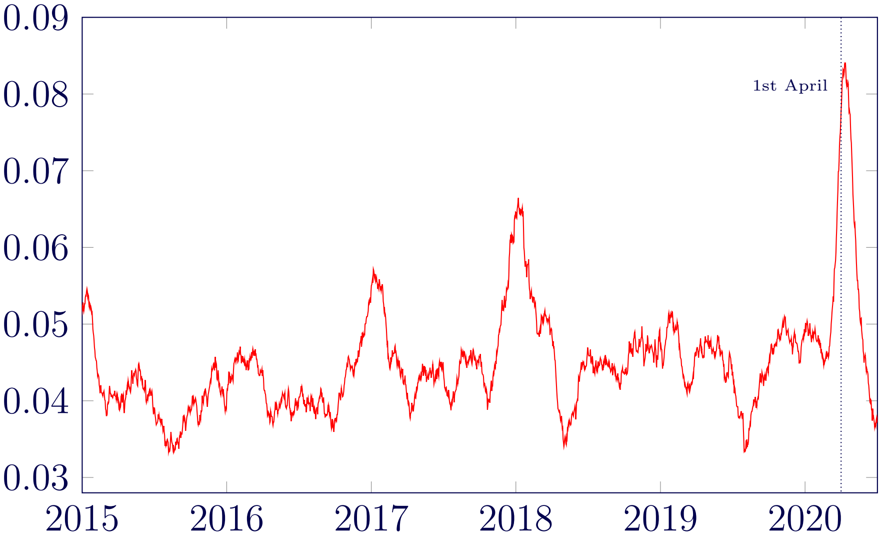

3 USA3 $\hat{\mu}_{2017+t}$, $c = 0.2$

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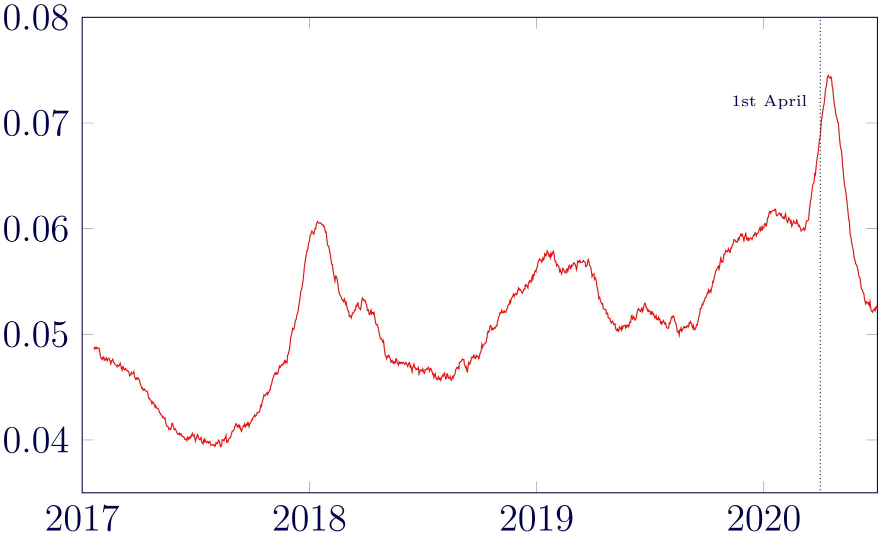

3 Non-parametric estimator

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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

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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

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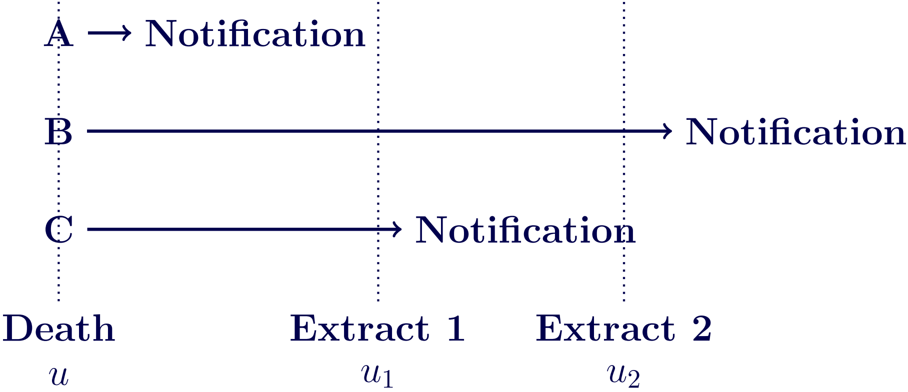
- Assume we have two extracts at time u_1 and u_2 $(u_1 < u_2)$.
- Assume a death occurs at time $u < u_1$.
- There are three possible reporting types...

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

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- 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].

4 Reporting delays

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

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

OBNR impact negligible when R is close to 1.

4 Impact of reporting delays

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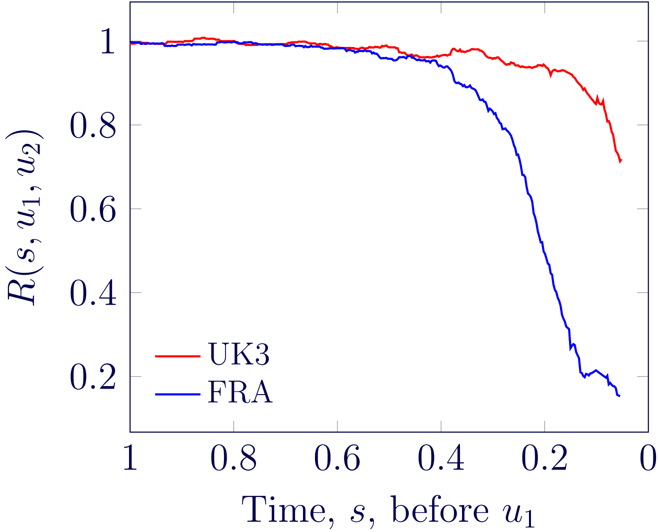

4 Reporting delays (OBNR)

- 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

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5 Reporting delays

Look again at the ratio measuring the impact of OBNR:

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

5 Reporting delays

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

We can re-arrange as follows:

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

5 Parametric approach

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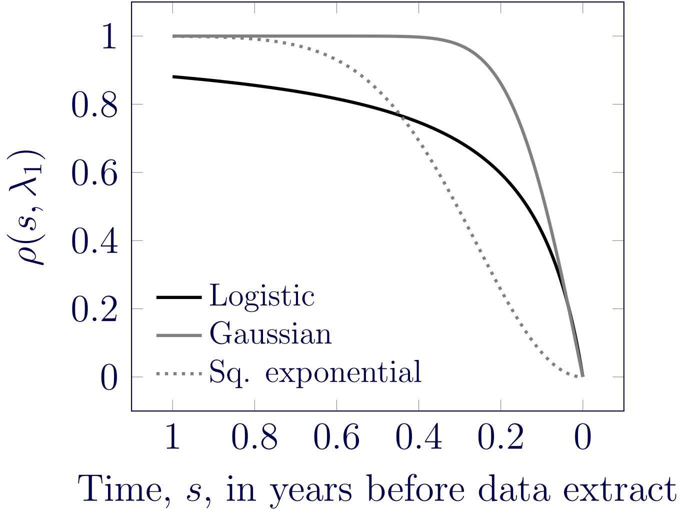
Model for OBNR-affected mortality, $\mu_{x,y}^{OBNR}$:

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

- $\mu_{x,y}^{OBNR}$ is reported mortality,
- $\mu_{x,y}^{*}$ is actual mortality experienced,
- $\rho(s, \lambda_1)$ is scaling factor for OBNR, and
- λ_1 is the OBNR decay parameter.

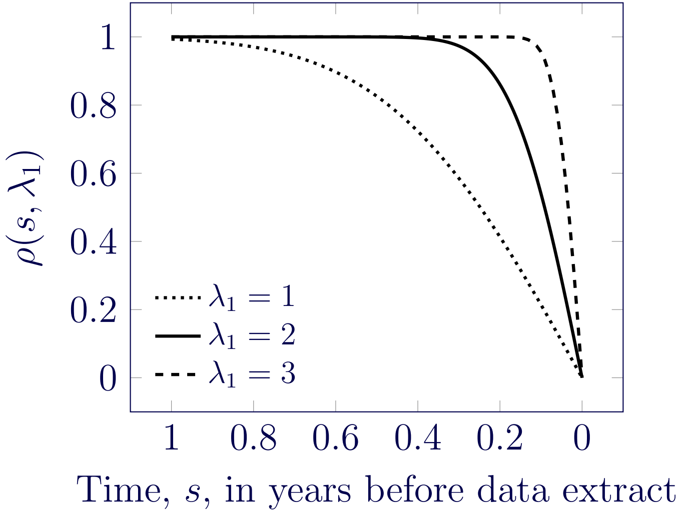
5 Options for $\rho(s, \lambda_1 = 2)$



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

5 Role of λ_1

Gaussian OBNR function:



5 Forecasting

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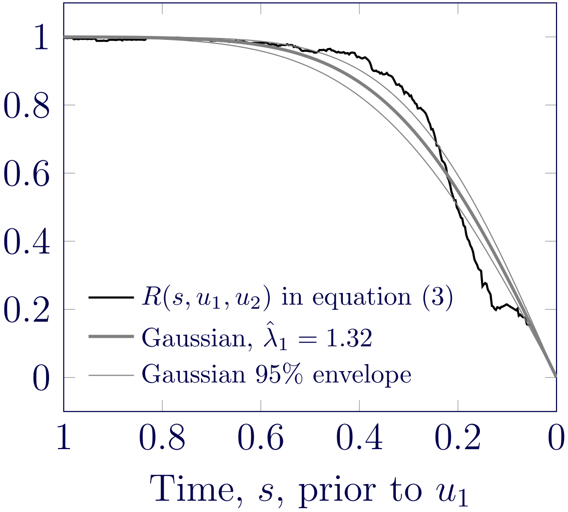
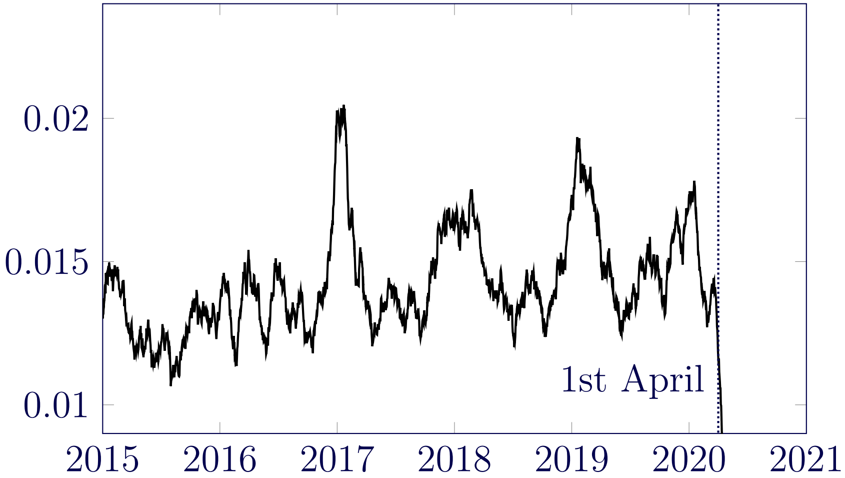
- Can we use a model at time u_1 to predict the unreported deaths by time u_2?
- Can we use the OBNR function to adjust for unreported deaths?

5 Forecasting OBNR



5 Adjusting for OBNR

FRA, June extract:



5 Adjusting for OBNR

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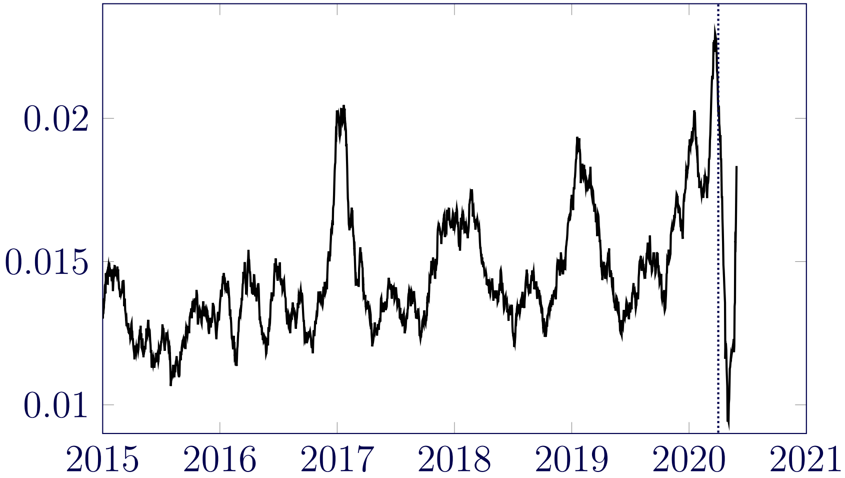
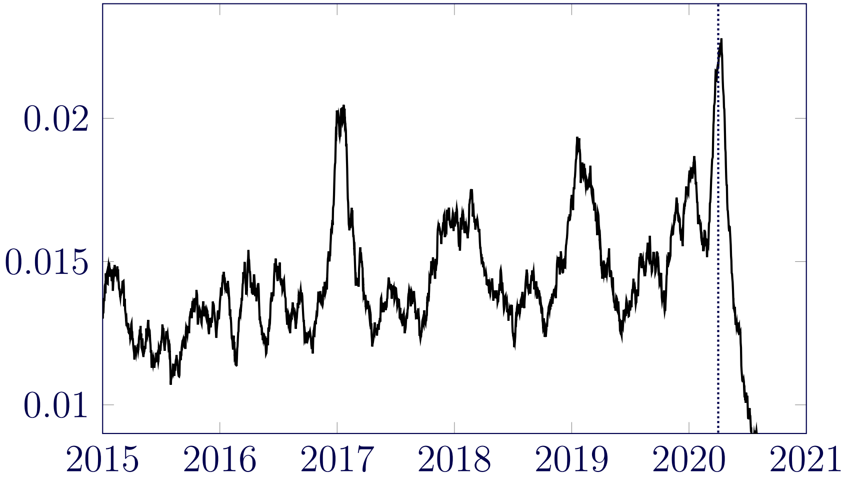
FRA, June extract with Gaussian OBNR adjustment:



5 Adjusting for OBNR

FRA, September extract:



6 Conclusions

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6 Conclusions — I

- 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.

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CCAES. Actualización no. 120. Enfermedad por el coronavirus (COVID-19). 29.05.2020. Technical Report 120, Centro de Coordinación de Alertas y Emergencias Sanitarias, May 2020.

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

Istat. Total deaths per age class, week of demographic event and municipality of residence at the time of death. Technical report, Istituto Nazionale di Statistica, 2020. URL `https://www.istat.it/en/archivio/240106`.

References II

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J. F. Lawless. Adjustments for reporting delays and the prediction of occurred but not reported events. *Canadian Journal of Statistics*, 22(1):15–31, 1994. doi: https://doi.org/10.2307/3315826.n1.

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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