PROJECTING MORTALITY IN POST-PANDEMIC ERA

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ISSUES

- ❖ Effects of Covid-19 on mortality rates
- ❖ Definition of an «acceleration» metric
- ❖ Assess the impact of acceleration on insurance market

ACCELERATION MODEL

$$A(x,t) = q(x,t) * SIRf(x,t) * \lambda(x,t)$$

$A(x,t)$ covid mortality rate at age *x* and time *t*

$q(x,t)$ death rate for the age x at time t computed in the absence of the pandemic

$SIRf(x,t)$ some measure of frailty

$\lambda(x,t)$ represents the infection rate

ACCELERATION MODEL

MOTIVATION

The impact of Covid-19 involves a higher exposure to mortality risk in the **less healthy** sub-population

ACCELERATION MODEL

To investigate the presence of mortality acceleration in the Italian population due to Covid-19 infection, we define:

- ❖ Impact of accelerated deaths on a cohort deaths' curve – based on empirical evidence from first and second waves;
- ❖ Impact of Covid-19 on future temporal evolution of deaths.

COVID-19 MORTALITY

Following Cairns et al. (2020), we consider the proportion $\pi(x,t)$ who will die from Covid-19 in a deterministic setting by the following formula:

$$\pi(x,t) = \frac{\alpha(x)}{\rho(x,t)} exp\left(\frac{-t}{12\rho(x,t)}\right)$$

We compute $\pi(x,t)$ comparing two scenarios:

1) on the SIIA clinical dataset (Scenario I);

2) on the ISS dataset (Scenario II).

DATASET

In order to estimate the acceleration factor we use the following datasets:

- ❖ SIIA dataset relating to an hospitalized population in 26 hospitals and centers, located in 13 regions in Italy (Iaccarino et al. 2020);
- ❖ ISS weekly bullettin, relating to the entire population (Istituto Superiore di Sanità 2020);
- ❖ All causes of death ISTAT dataset (ISTAT 2020).

AMPLITUDE

Amplitude parameter $\alpha(x)$ is approximated as the proportion of Covid-19 deaths at age x. Since Italian data about Covid-19 deaths is not available, we proceed as follows:

- ❖ The proportion of deaths at age x among Covid-19 deaths is estimated, referring to the two informative datasets (ISS and SIIA);
- ❖ The number of deaths by age from Covid-19 is estimated by multiplying the proportion at age x by the total;
- ❖ The proportion of deaths from Covid-19 to the total deaths is calculated using ISTAT mortality data.

REACH

Reach parameter $\rho(x)$ is approximated as the loss in terms of life expectancy at age x due to Covid-19 deaths and it is estimated as follows:

- Life expectancy at age x is estimated for the year 2020;

- The lost years of life expectancy for each age are calculated x as the product of the weight by age of deaths from Covid-19, or the proportion of deaths for age x out of the total, and life expectancy at age x.

COVID-19 DEATHS

Once $\alpha(x)$ and $\rho(x)$ are calculated, it is possible to estimate the acceleration factor for age $\pi(t, x)$.

$\pi(t, x)$ allows us to project Covid-19 deaths as the sum of the products of the projections of deaths from all causes and the acceleration of mortality for each year.

In this case, the mortality data for 2020 are projected.

RESULTS

We compare the results for the first and the second wave, considering the following specifc time intervals:

- **First wave:** 24^{th} February 2020 to 15^{th} May 2020;

- **Second wave:** from 15^{th} May 2020 to 30^{th} November 2020.

FIRST WAVE DATA

age	SIIA scenario			ISS scenario		
	amplitude	reach	acceleration	amplitude	reach	acceleration
0-9	0.000	0.000	0.000	0.003	0.010	0.270
10-19	0.169	0.254	0.650	0.000	0.000	0.000
20-29	0.230	0.677	0.321	0.008	0.024	0.342
30-39	0.365	1.614	0.197	0.022	0.096	0.226
40-49	0.263	3.080	0.066	0.029	0.345	0.083
50-59	0.233	5.088	0.030	0.049	1.059	0.042
60-69	0.129	4.061	0.023	0.070	2.209	0.026
70-79	0.085	3.447	0.019	0.091	3.672	0.018
80-89	0.042	1.555	0.023	0.080	2.984	0.021
90+	0.014	0.171	0.079	0.046	0.575	0.077

FIRST WAVE DATA

- *Amplitude* differs in the two scenarios in the proportion of deaths by ages. SIIA data presents higher Covid-19 related mortality for all age groups, except ages 0-9. This suggests that, for the same age, hospitalized persons have a greater risk of death from Covid-19 than other infected persons.
- Also for *reach* the two scenarios differ considerably. In particular, in the scenario based on the SIIA data, the expected loss of years of life is more severe in the middle ages, with a maximum of 5 years lost on average for ages 50-59 and, although not null, the loss is more limited for the advanced ages. In contrast, for the ISS scenario, it is the ages over 60 who are most penalized by the reduction in life expectancy.
- For the values of *acceleration*, we observe similar results; that is a greater acceleration of mortality in the younger ages, but a greater mortality in the more advanced ages in absolute terms. This is due to the fact that mortality at low or middle age causes a greater loss in terms of life expectancy than in older ages.

SECOND WAVE DATA

age	SIIA scenario			ISS scenario		
	amplitude	reach	acceleration	amplitude	reach	acceleration
0-9	0.000	0.473	0.000	0.006	0.011	0.546
10-19	0.272	1.195	0.206	0.005	0.004	0.990
20-29	0.352	2.976	0.092	0.015	0.025	0.602
30-39	0.364	5.311	0.044	0.037	0.099	0.376
40-49	0.167	6.898	0.014	0.052	0.357	0.140
50-59	0.318	6.226	0.030	0.069	1.051	0.061
60-69	0.353	5.388	0.042	0.095	2.135	0.037
70-79	0.143	1.943	0.062	0.108	3.481	0.023
80-89	0.014	0.296	0.045	0.087	2.993	0.023
90+	0.003	0.018	0.174	0.060	0.628	0.091

SECOND WAVE DATA

- *Amplitude* is higher for ages up to 69 in the SIIA scenario than in the ISS scenario, it is similar for ages 70 to 90 and lower for ages 90+. In other words, the SIIA scenario places more emphasis on ages that are not extreme than the ISS scenario. This aspect, as in the previous case, depends on the level of hospitalizations.
- *Reach* is higher for ages up to 69 years in the SIIA scenario than in the ISS scenario, with a loss of life expectancy up to around 5 to 7 years in the age groups between 30 and 69 which, in this case, are the most affected groups. In contrast, in the ISS scenario, the most affected age groups are those between 60 and 89 years, with a loss of life expectancy between 2 and 3 years approximately.
- *Acceleration* based on the SIIA scenario and the ISS scenario differ according to the age group. The acceleration increases with increasing age, an aspect that depends on the base scenario; the SIIA scenario tends to overestimate the acceleration due to Covid-19 compared to the SIIA scenario for all ages. This aspect underlines the importance of distinguishing between frail and non-frail populations in the context of an analysis of the effects of Covid-19 mortality.

ACCELERATION MODEL

$$A(x,t) = q(x,t) * SIRf(x,t) * \lambda(x,t)$$

$A(x,t)$ covid mortality rate at age x and time t

$q(x,t)$ death rate for the age x at time t computed in the absence of the pandemic, measured by Renshaw-Haberman model (Renshaw and Haberman, 2006)

$SIRf(x,t)$ smoothed implied relative frailty for the age x at time t smoothed by age using a *p*-spline function

$\lambda(x,t)$ the infection rate measured by a Gompertz dynamic model as defined by Harvey et *al*. (2020)

MORTALITY IN ABSENCE OF PANDEMIC

To estimate $q(x,t)$ we use data from 1950 to 2017 ranging from 0 to 110 ages aggregated by gender from the Human Mortality Database, based on all causes of death.

This model represents the **scenario in the absence of a mortality pandemic.**

MORTALITY IN ABSENCE OF PANDEMIC

	AIC	BIC
Basic LC	177938	177938
RH	131810.9	134784
APC	245248.1	247530.8
M7	3557937	3560459

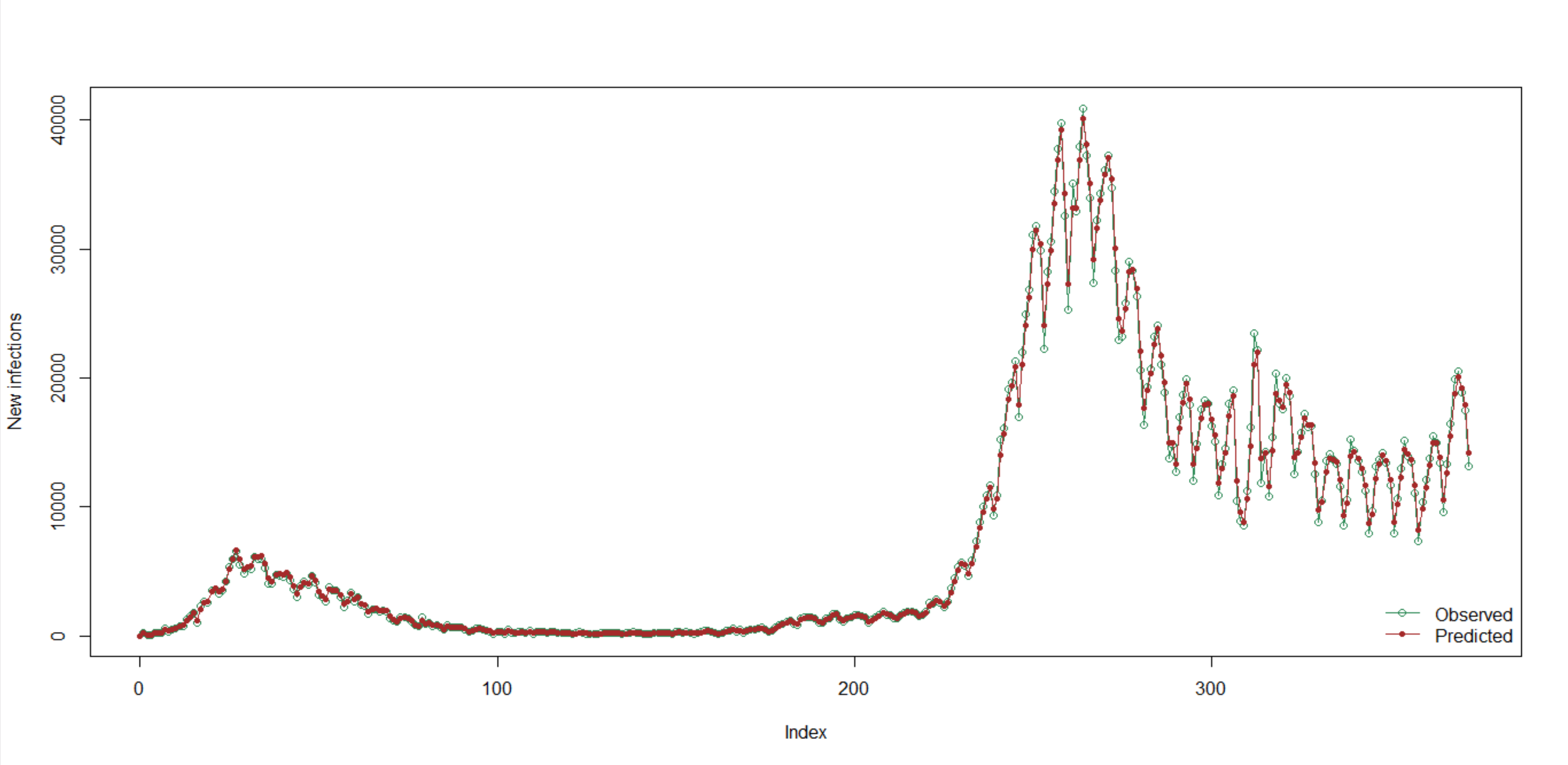
INFECTION RATE

In order to choose the best predictor for the infection rate, we estimate a Gompertz dynamic model as defined by Harvey and Kattuman (2020). This model is based on a dynamic linear model, largely used in time series data to model time-varying parameters.

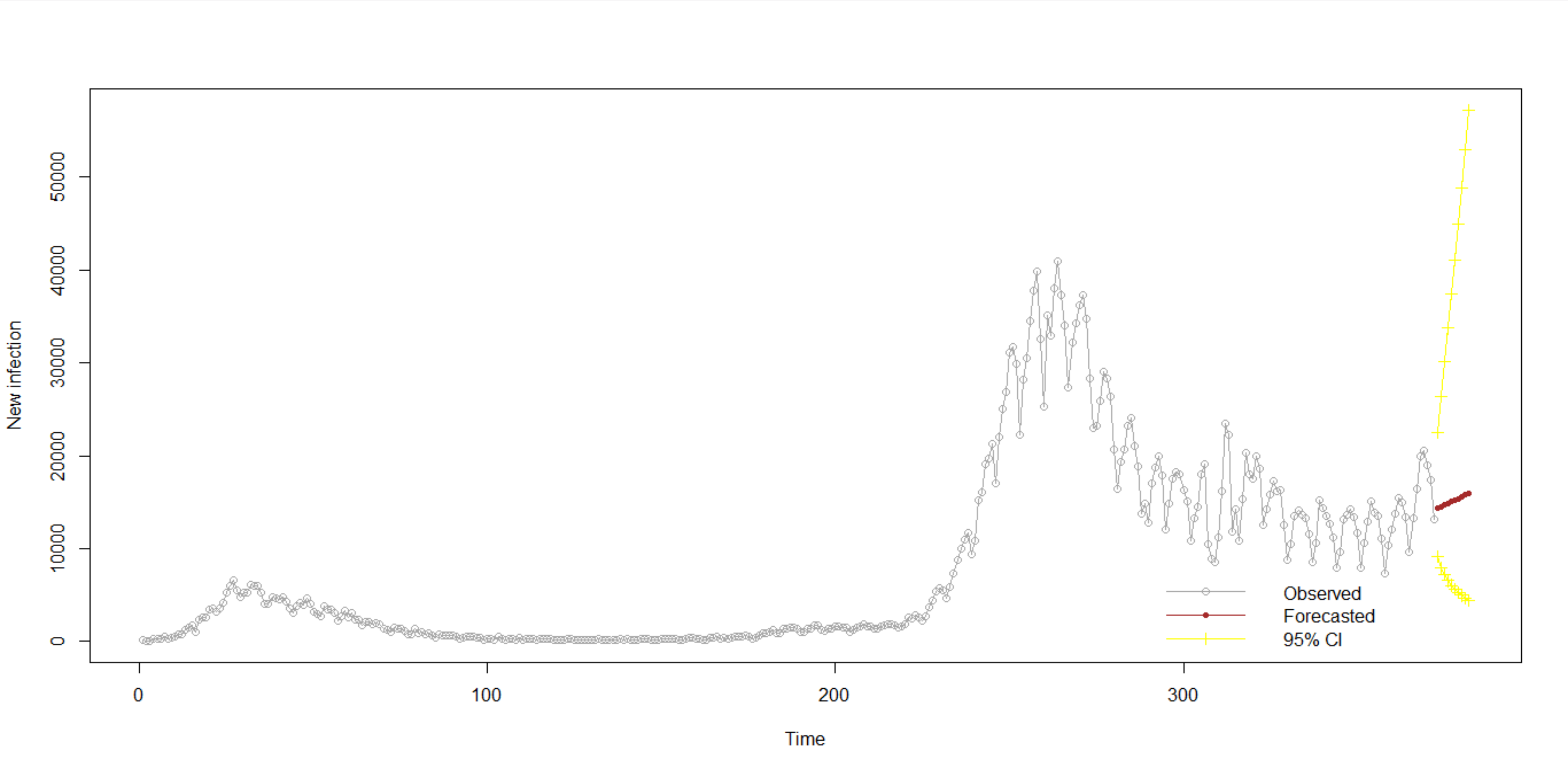
As shown by the authors, the model of new infection growth rate, that is $\log(y_t - y_{t\text{-}1})$ is modelled as a *random walk with drift* and an *exogenous trend*.

The infection rate is estimated from the Protezione Civile's time series, that reports the number of new daily infected aggregated for all ages. In order to obtain the infection rate, we use the log-difference of the series.

INFECTION RATE



INFECTION RATE



SMOOTHED IMPLIED RELATIVE FRAILTY

Implied relative frailty is calculated using observed data, since all of the other elements, except for relative frailty, are observed.

From an inverse formula based on $A(x,t)$, we obtain an implied “frailty score” for all of the ages groups.

SMOOTHED IMPLIED RELATIVE FRAILTY

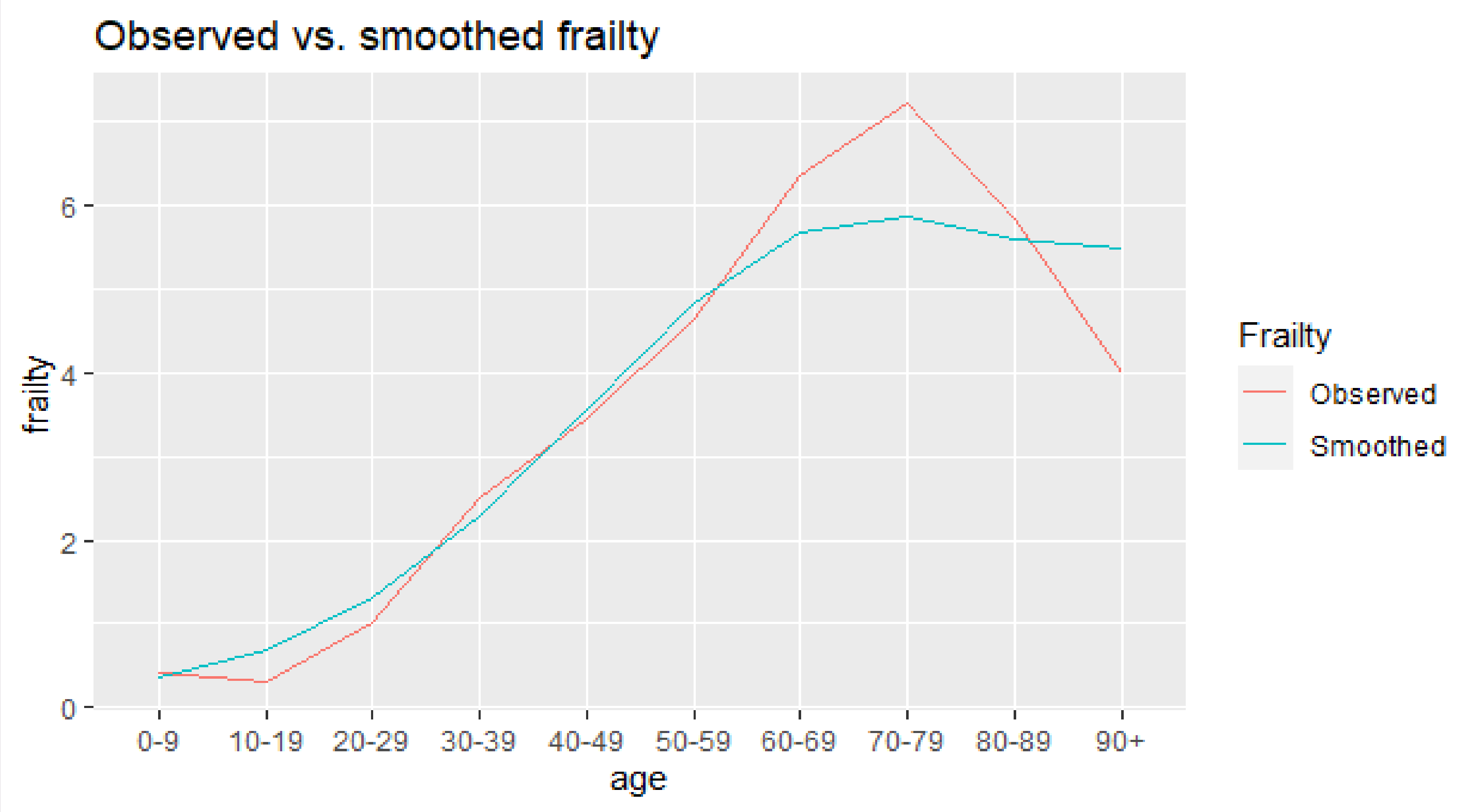
age	implied frailty
0-9	0.403
10-19	0.302
20-29	1.001
30-39	2.495
40-49	3.443
50-59	4.631
60-69	6.339
70-79	7.219
80-89	5.822
90+	4.004

Implied frailty shows an increasing value up to 70-79 age class and then it decreases.

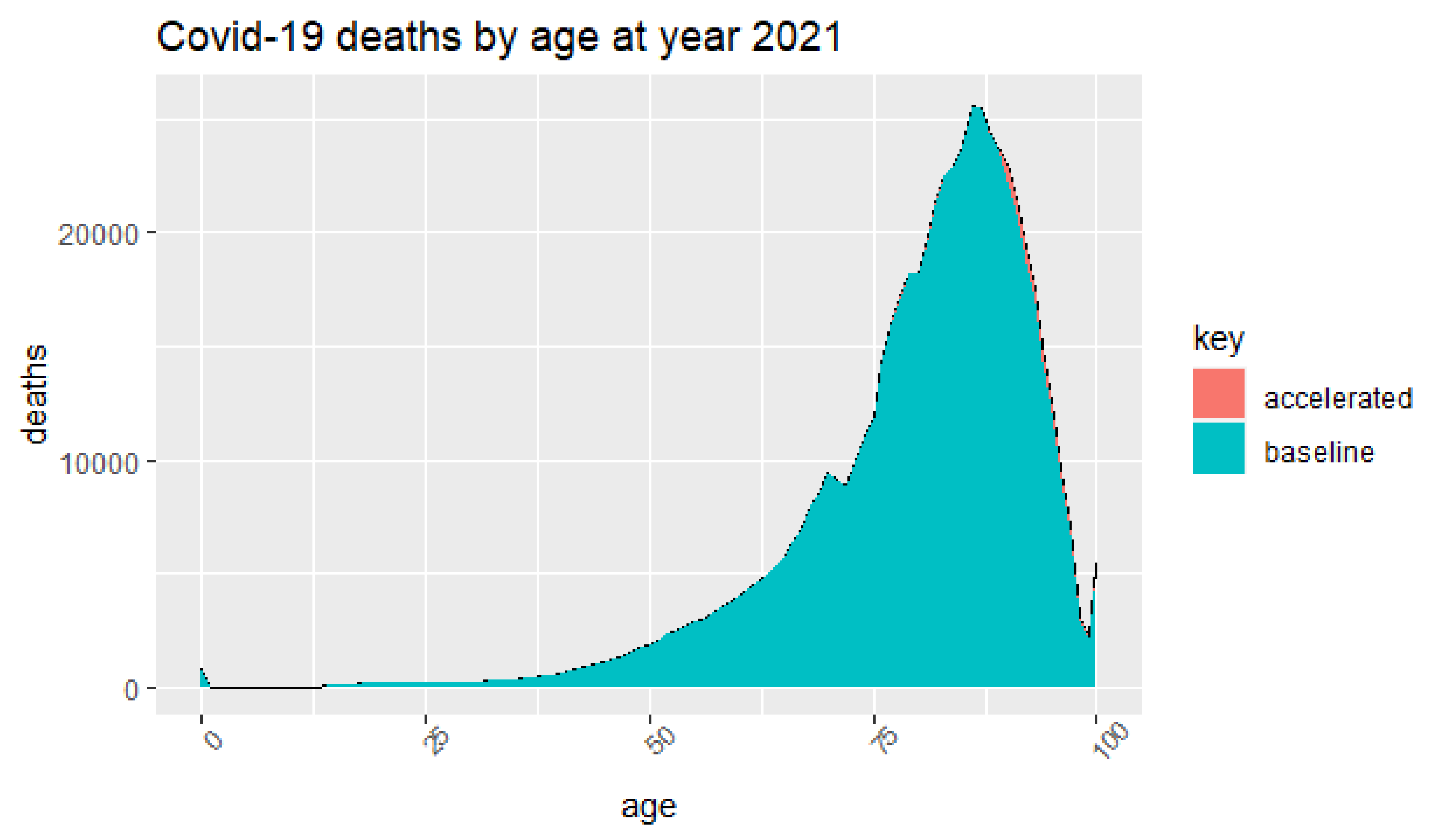
In order to improve results of estimated Covid-19 mortality rates, we use a *p*-spline smoothing to better reshape the implied frailty estimation and obtain an increasing function by age.

The smoothing is applied using the all-causes mortality rate by age as offset.

SMOOTHED IMPLIED RELATIVE FRAILTY



COVID-19 MORTALITY



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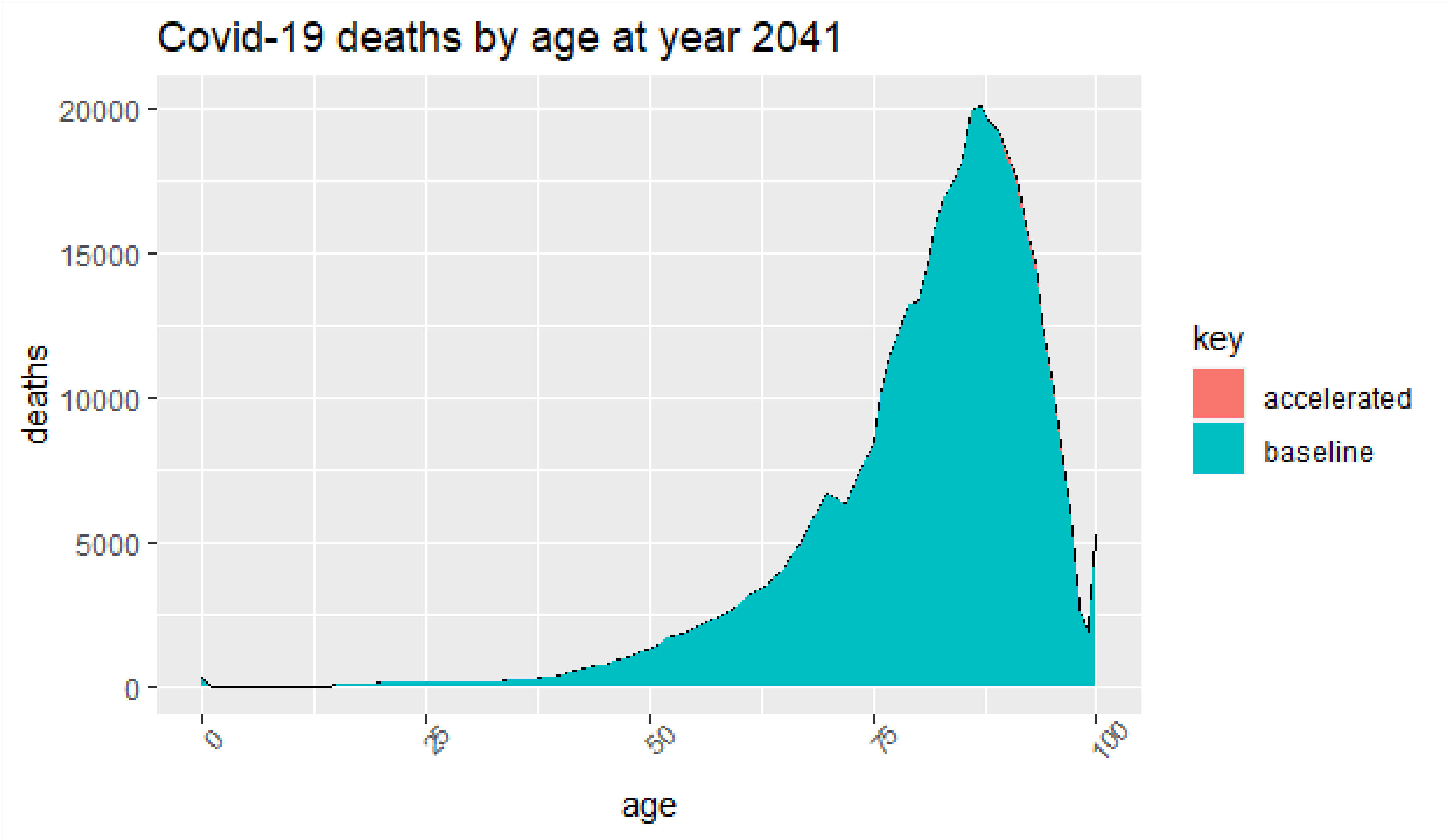

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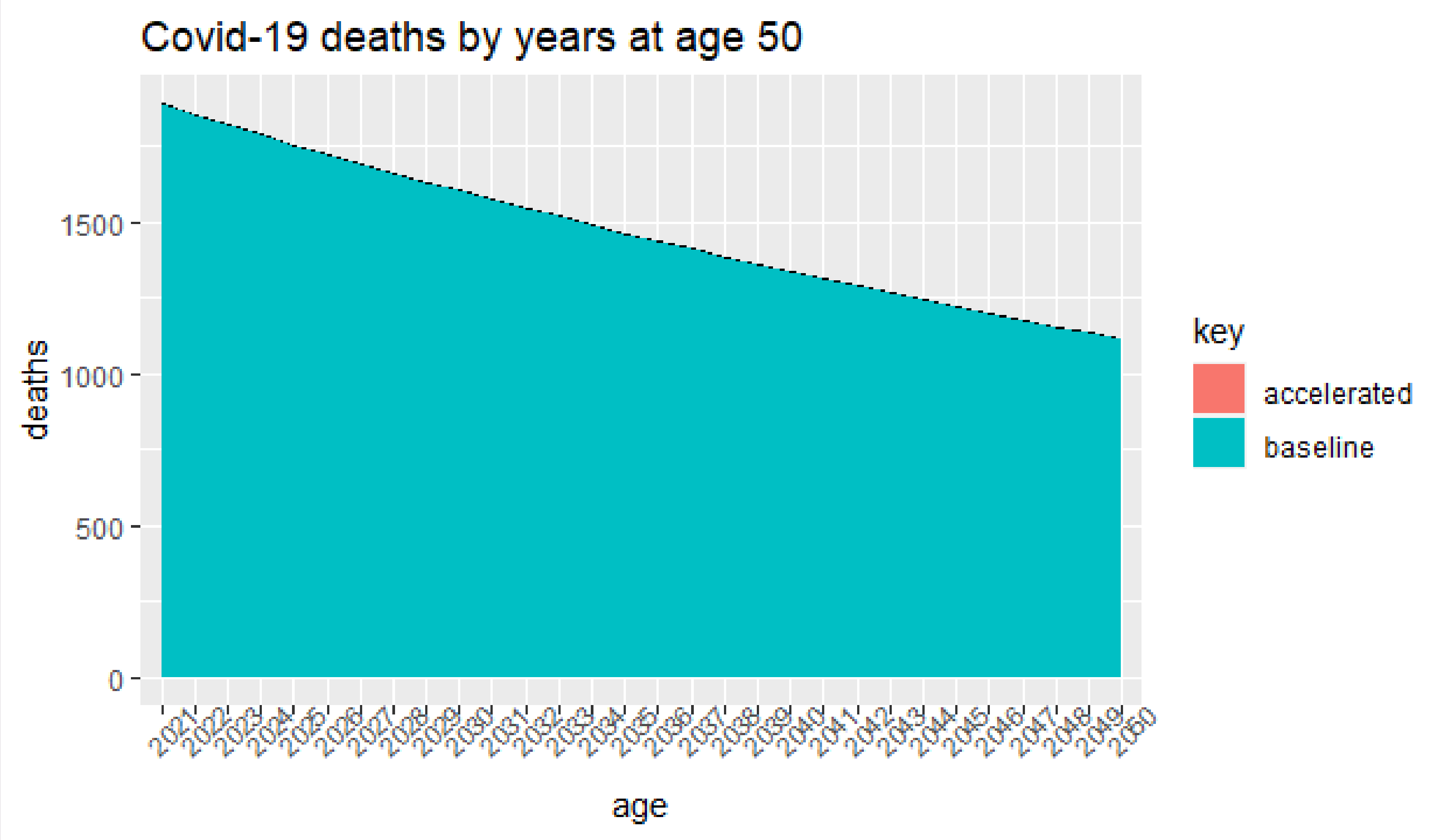
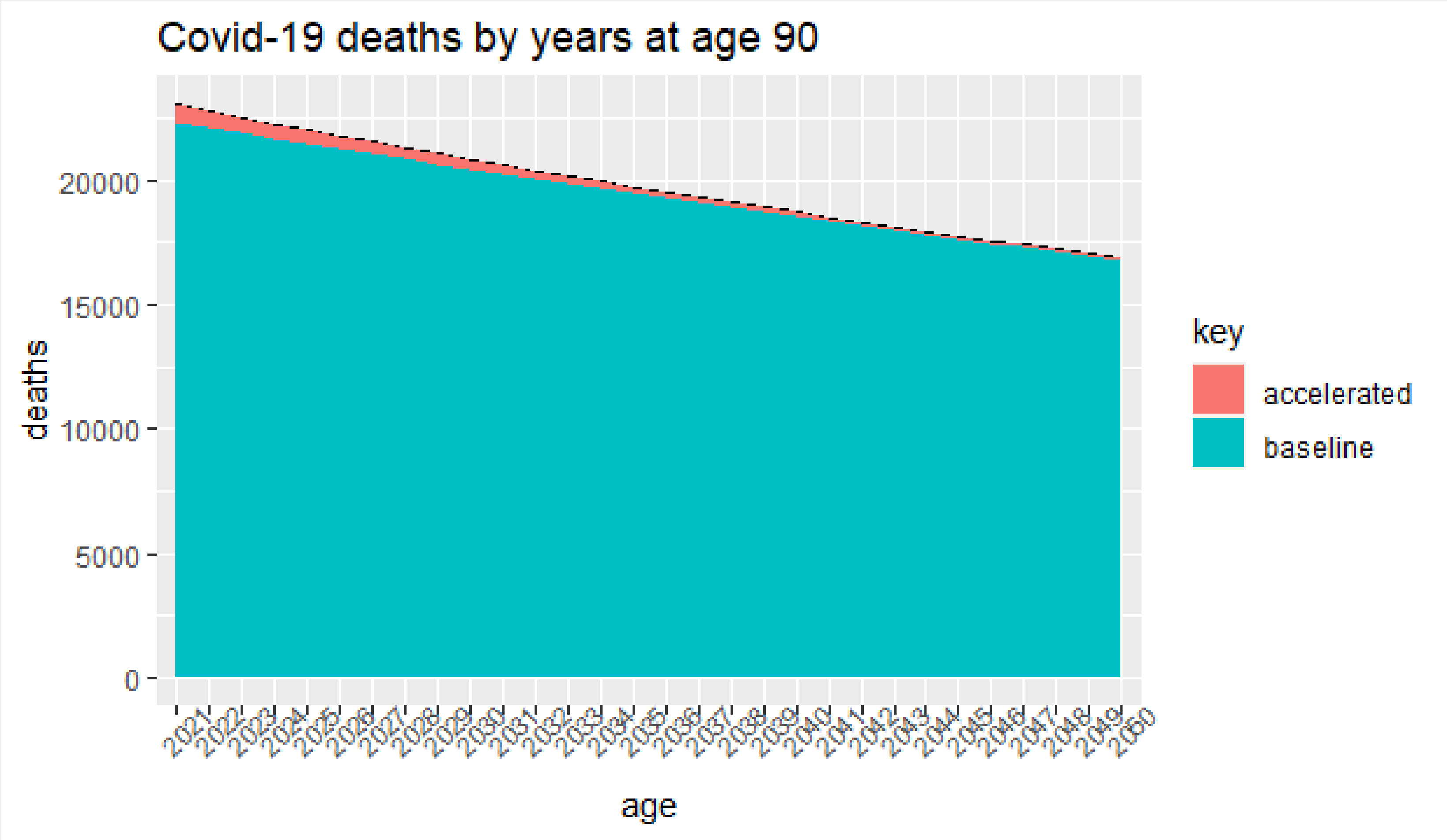


COVID-19 MORTALITY



COVID-19 MORTALITY

As can we observe from the figures:

- ❖ Covid-19 mortality rates is a short-term phenomenon. Although it affects the most frail part of the population, there appears to be no long-term repercussions in terms of premature deaths;

- ❖ Covid-19 mortality has some persistence in the elderly population compared to the younger population; however, the impact on mortality is marginal with respect to longevity effects on the population.

ACCELERATION METRICS

Acceleration ${}^{MA}_{t}\vartheta_x$ as the spread between the mortality projections:

$$ {}^{MA}_{t}\vartheta_x = Acc_{q(x,t)} - Base_{q(x,t)} $$

Acceleration Insurance Ratio AIR:

$$ AIR = \frac{\Pi}{{}^{Baseline}\pi} $$

where $\Pi = {}^{ACC}\pi - {}^{Baseline}\pi$ represents a measure we called *Premium Acceleration* ${}^{Baseline}\pi$ the Baseline Single Premium

IMPACT ON INSURANCE MARKET

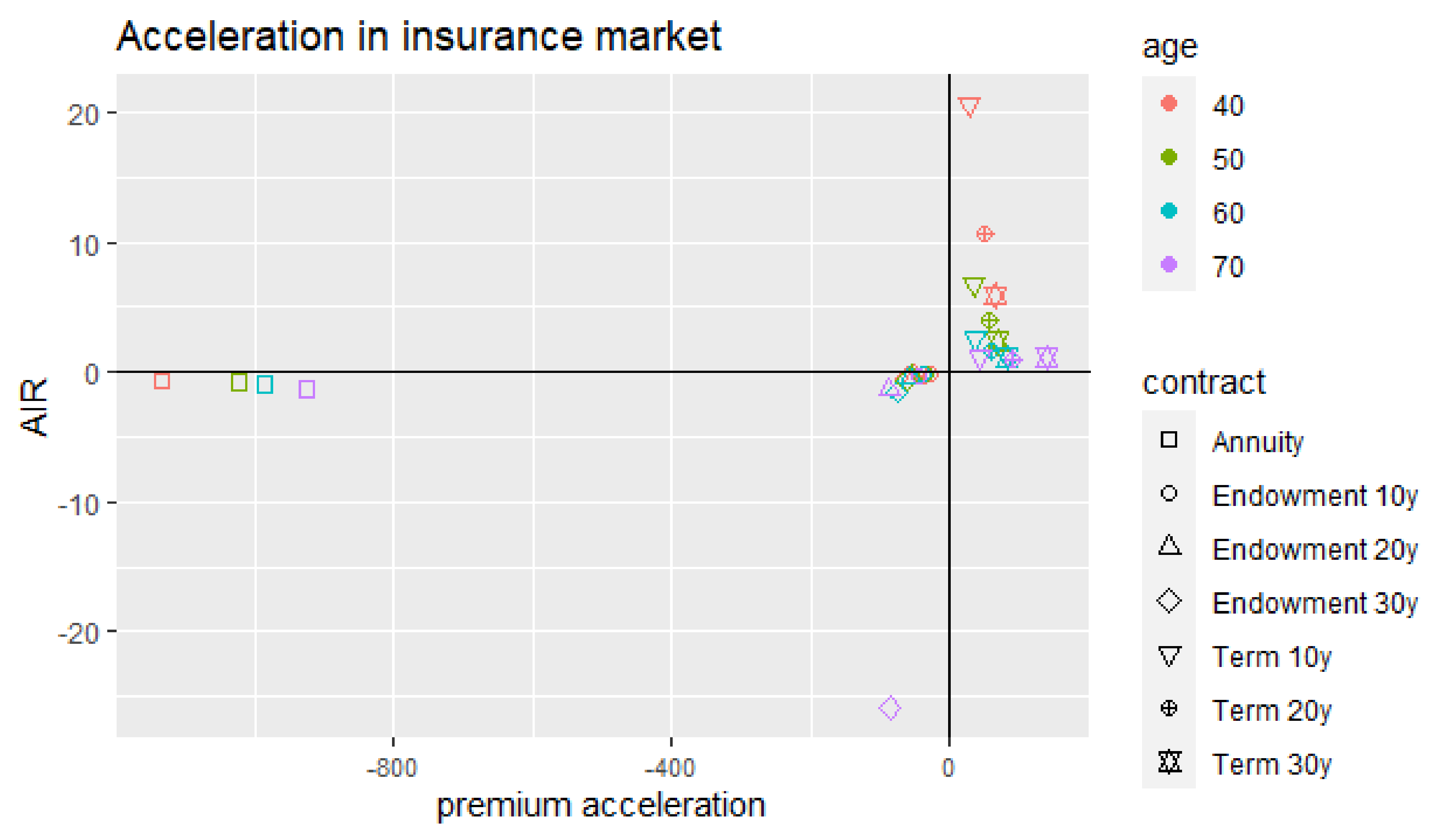
In order to assess the impact of Covid-19 mortality acceleration on the insurance market, we compare the premiums of some of the main (non-participating) life contracts using survival probabilities from the baseline and accelerated cases.
In particular, we consider, for persons aged x = 40, 50, 60, 70 and t = 2022:

1. An immediate annuity with a technical rate of 1% and an annual payment of 5,000;

2. A term insurance with a technical rate of 4% and a insured amount of 25,000 for 10, 20 and 30 years;

3. A pure endowment with a technical rate of 2% and a insured amount of 25,000 for 10, 20 and 30 years.

IMPACT ON INSURANCE MARKET



IMPACT ON INSURANCE MARKET

- *Comparison by contracts*: for all the ages considered, Immediate Annuity has negative premium acceleration and AIR; Pure Endowment has a negative premium acceleration and AIR that increases (in absolute values) as the duration increases; and Term Insurance has a positive premium acceleration, that increases as the duration increases and a positive AIR that decreases as the duration increase;

- *Comparison by age*: premium acceleration increases in absolute values for the Term Insurance and Pure Endowment with equal durations and it decreases for the Immediate Annuity. In contrast, considering the AIR, the relative difference increases for the Immediate Annuity and Pure Endowment and it decreases for the Term Insurance.

CONCLUDING REMARKS

- Comparing the first and the second waves, we observe - alongside an age effect – a frailty effect on mortality caused by Covid-19, related to the hospitalized sub-population. The effect is more evident in the second wave, where the access to medical treatment was open to people of all ages.

- Estimation of the projections of Covid-19 mortality rates allows us to evaluate the effects by age and time of Covid-19 on mortality. As observed, although it persists for some higher ages, mortality rates are not affected by the Covid-19 pandemic in the long term.

- In the life insurance market, the effects of the pandemic on mortality are smaller than the effect due to increasing age. For this reason, although an extra premium is observed, the difference is smaller than the difference arising from increases in the insured person's age. This result seems to suggest that the impact of the pandemic on the insurance market, although it is not zero, is nevertheless modest.

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THANKS FOR YOUR ATTENTION!

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