COVID-19 Mortality

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Outline

- The purpose of this exercise is to analyze the impact of COVID-19 on the mortality of the German population.
- As a benchmark, we use the mortality rates of 2017 computed from the Human Mortality Database. Estimated infection fatality ratios of COVID-19 are taken from Imperial College COVID-19 Response Team (March 16, 2020).
- We provide a continuum of case studies varying a scenario parameter that simultaneously captures two effects:
 - Imperial College estimates may overstate the true mortality; infection fatality ratios might thus only be a fraction of these estimates.
 - Over the relevant period of the virus pandemic, only a proportion of the population might be infected.
- A key assumption of our computation is that the duration of the epidemic is at most one year and that mortality rates return to the benchmark levels afterwards.

Outline (2)

- The second key parameter that we vary characterizes which percentage of COVID-19 mortality is absorbed by the regular death rate. We call this parameter **overlap**.
 - An overlap of 0 denotes the worst case; an overlap of 1 corresponds to the case that all COVID-19 mortality is absorbed by the benchmark mortality.
- As a function of scenario parameter, overlap, and age, we characterize annual mortality rates and numbers of additional deaths.
- In addition, we compute for increased annual mortality rates due to COVID-19 the equivalent age of a person in a scenario where the epidemic is not present. We obtain equivalent age increments.
- Under the assumption that mortality rates return to their regular levels after one year, we compute the COVID-19 decrease of period life expectation and determine the historical year with the same period life expectation.
- The corresponding MATLAB code is available on our website www.insurance.uni-hannover.de.

German Population Data



Population exposed to death risk and number of deaths in Germany for the benchmark year 2017. The aggregate number of deaths equals 932,263. Data are provided by the Human Mortality Database (HMD).

COVID-19 Mortality Data



Estimated COVID-19 infection fatality ratios with a cubic spline fit plotted together with German regular death rates in 2017. Infection fatality ratios are provided by the Imperial College London COVID-19 Response Team (March 16, 2020), mortality data are obtained from the HMD.

Scenario Parameter κ

- In our case studies, we vary a scenario parameter $\kappa = \alpha \cdot \beta$ that captures two effects:
 - Only a proportion α of the population might become infected by the virus.
 - True infection fatality ratios might only be a fraction β of estimated rates.
- We consider three different scenarios: $\kappa \in \{1, 0.5, 0.1\}$.
- For illustration, the following table provides various combinations of α and β that lead to these scenarios:

κ	corresponding to tuples $(lpha, eta)$ or $(eta, lpha)$, respectively											
1	(1,1)											
0.5	(1,0.5)	(0.9,0.556)	(0.8,0.625)	(0.7, 0.714)	(0.6,0.833)							
0.1	(1, 0.1)	(0.9, 0.111)	(0.8, 0.125)	(0.7,0.143)	(0.6, 0.167)	(0.5, 0.2)	(0.4,0.25)	(0.3,0.333)				

Specific Example for Illustration: For example, if $\alpha = 50\%$ of the population experiences an infection and if the true infection fatality ratios are $\beta = 20\%$ of the reported estimates, the scenario parameter is $\kappa = 0.1$.

Overlap

- An unknown proportion of COVID-19 mortality will be absorbed by the regular mortality of the population.
- We vary this parameter which we call overlap:
 - ► 100% Overlap

 \rightarrow The number of deaths is not increased due to COVID-19, but COVID-19 mortality is fully absorbed by the regular population mortality according to the benchmark year 2017.

► 0% Overlap

ightarrow All deaths due to COVID-19 are in addition to benchmark mortality.

► x% Overlap

 \rightarrow A fraction x% of deaths due to COVID-19 is absorbed by the benchmark mortality.

Death Rates



One-year death rates and COVID-19 multiplier of death rates in Germany, as a function of age and overlap, for the scenarios (from left to right) $\kappa = 1, 0.5, 0.1$.

Death Rates (2)

- The upper displays of the previous slide show the death rates in Germany for the three scenarios $\kappa = 1, 0.5, 0.1.$
- The lower displays show the corresponding COVID-19 multiplier of the death rates. The multiplier is defined as the ratio of the annual death rate in the presence of COVID-19 divided by the annual death rate of the benchmark year 2017.
- In the scenario $\kappa = 1$, the multiplier is at most 3 for no overlap; if overlap is 50%, the multiplier is approximately bounded by 2.

Additional Deaths due to COVID-19



Additional deaths due to COVID-19, for the overall population in the different scenarios, and in scenario $\kappa = 1$ differentiated by age group.

Additional Deaths due to COVID-19 (2)



Additional deaths due to COVID-19 in scenarios $\kappa = 0.5, 0.1$ differentiated by age group.

Additional Deaths due to COVID-19 (3)

- For $\kappa = 1$ and low overlap, the aggregate number of additional deaths due to COVID-19 will exceed one million.
- For κ = 0.5 and a large overlap of about 3/4, the aggregate number of additional deaths due to COVID-19 will still exceed 100,000.
- The number of additional deaths increases strongly with age for all scenario and overlap parameters.

Equivalent Age Increments in the Year of the Epidemic

- As a benchmark for regular death rates, we chose the year 2017.
- COVID-19 increases death rates. The size of the increments is a function of scenario and overlap parameter as well as age.
- For an increased annual mortality rate of a person of a certain age we determine the age of a person with the same mortality rate in the benchmark year 2017. In this sense, an increase of mortality rates due to COVID-19 corresponds to an hypothetical age increase in the benchmark year.
- We call this age difference the **equivalent age increment** and analyze this quantity on the next slide.

Equivalent Age Increments in the Year of the Epidemic (2)



Equivalent age increment of annual mortality rates in Germany in the year of the epidemic – as a function of age and overlap, for the scenarios (from left to right) $\kappa = 1, 0.5, 0.1$.

Decreased Life Expectancy

- Mortality increases during the epidemic; under the assumption that mortality rates return to their normal levels after one year, we compute period life expectancies.¹
- As shown on the next slide, period life expectancies decrease in all scenarios and for all ages by less than a year. For individuals under the age of 50, the decrease in period life expectancy is very small.
- Finally, for all ages up to 80, we determine the closest historical year with the same period life expectancy as computed in presence of COVID-19. It turns out to be sufficient to include mortality data of the previous 20 years.

¹Computed by the algorithm outlined in Section 1.1 of *Methoden- und Ergebnisbericht zur laufenden Berechnung von Periodensterbetafeln für Deutschland und die Bundesländer*, Statistisches Bundesamt, 2019

COVID-19 Period Life Expectancy



Average period life expectancy and its decrease due to COVID-19 (only affecting the current one-year mortality rates) in Germany as a function of age and overlap, for the scenarios (from left to right) $\kappa = 1, 0.5, 0.1$.

COVID-19 Period Life Expectancy - Historical Comparison



Historical year corresponding to the decreased period life expectancy due to COVID-19 in Germany as a function of age and overlap, for the scenarios (from left to right) $\kappa = 1, 0.5, 0.1$. Ages beyond 80 are not considered due to significant fluctuations in the mortality time series of these age groups.

References

- Ferguson, N. M. et al.; on behalf of the Imperial College London COVID-19 Response Team: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand, March 16, 2020, https://doi.org/10.25561/77482.
- Human Mortality Database. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded on March, 17, 2020).
- Statistisches Bundesamt (Destatis): Methoden- und Ergebnisbericht zur laufenden Berechnung von Periodensterbetafeln für Deutschland und die Bundesländer, November 5, 2019.

Appendix: Specific Example Values

		Additic	COVID-19 Multiplier								
	Total	under 50	between 50-70	over 70	Age 20	30	40	50	60	70	80
Worst Case $\kappa=1$, Overlap=0%	1,331,571	36,337	346,412	948,823	1.47	2.27	2.14	2.18	2.77	3.09	2.57
Moderate Case $\kappa=$ 0.5, Overlap=70%	199,736	5,450	51,962	142,323	1.07	1.19	1.17	1.18	1.27	1.31	1.24

	Equivalent Age Increment						Decrease of Period Life Expectancy						
	Age 30	40	50	60	70	80	Age 20	30	40	50	60	70	80
Worst Case $\kappa=1$, Overlap=0%	11	8	7	12	11	7	0.01	0.03	0.04	0.09	0.30	0.55	0.61
Moderate Case $\kappa=$ 0.5, Overlap=70%	2	2	1	2	3	2	0.001	0.004	0.007	0.01	0.05	0.08	0.09