Direct and indirect effects of the COVID-19 pandemic on mortality in Switzerland

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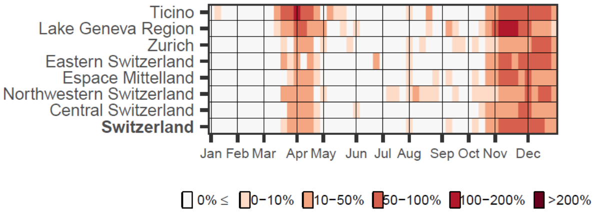
Outline

Introduction

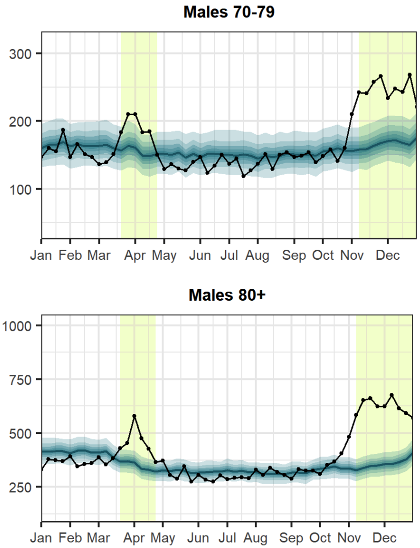
COVID-19 death burden

- 6 million laboratory-confirmed deaths globally: July 12, 2022.
- COVID-19 lab deaths:
  - accuracy, completeness, different definitions
  - deaths due to disruptions in social and economic life
- Excess all cause-mortality: observed versus expected had the pandemic not occurred
- In Switzerland in 2020 $\sim 6,000$ excess deaths



Direct and indirect effects of the pandemic

- Most studies have focused on calculating excess or reporting lab deaths.
- Direct (deaths followed a SARS-CoV-2 infection) or indirect (deaths caused or avoided due to our response to tackle the virus) deaths.
- Central to gauging the appropriateness of COVID-19 control measures



Aims

1. Estimate the excess mortality in Switzerland over epidemic phases, age groups and cantons.
2. Compare the excess mortality with laboratory confirmed SARS-CoV-2 deaths over epidemic phases, age groups and cantons.

Methods

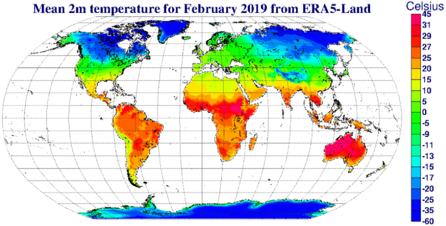
Data

All cause deaths - lab deaths - population

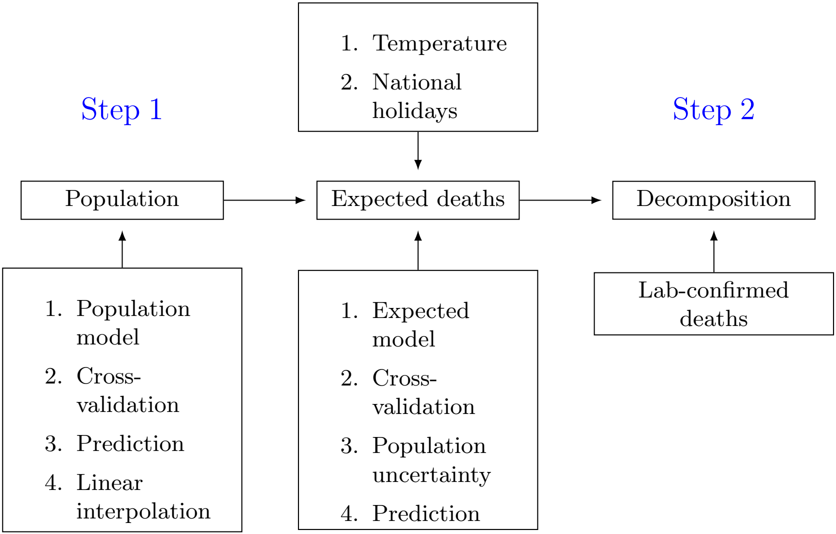
- Federal Statistical Office
- Age (0-39, 40-59, 60-69, 70-79 and $>$80), sex and canton.
- All cause deaths weekly for 2010-2022, lab deaths weekly for 2020-2022, population annually 2010-2019

Covariates

- Daily temperature at 9$\times$9 km: ERA5 reanalysis data
- National holidays (1-If week includes a national holiday)



Our approach



Step 1: Population models

Let P_{ijkl} be the population for the i-th sex (male-female), j-th age-group ($<$40, 40-59, 60-69, 70-79, ≥ 80), k-th year (2010-2019) and l-th canton. Let X_{1i} be the sex and X_{2k} be the year covariate

$$P_{ijkl} \sim \text{Poisson}(\mu_{ijkl})$$

$$\log(\mu_{ijkl}) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2k} + b_{jkl}$$

Model	Abbreviation	b_{jkl}
1	BASE	$w_j + v_k + u_l$
2	OV	$w_j + v_k + u_l + \xi_{jkl}$
3	OV_INT	$w_j + v_k + u_l + w_j \otimes v_k + w_j \otimes u_l + v_k \otimes u_l + \xi_{jkl}$
4	VC	$w_j + v_k + u_l + \beta_{2jkl} X_{2k}$
5	VC_OV	$w_j + v_k + u_l + \xi_{jkl} + \beta_{2jkl} X_{2k}$
6	VC_OV_INT	$w_j + v_k + u_l + w_j \otimes v_k + w_j \otimes u_l + v_k \otimes u_l + \xi_{jkl} + \beta_{2jkl} X_{2k}$

Step 1: Expected deaths model

Let Y_{jtkl} be the number of all-cause deaths, P_{jtkl} be the population at risk and r_{jtkl} the risk in the j-th age-sex group, t-th week, k-th year and l-th canton:

$$
\begin{aligned}
Y_{jtkl} &\sim \text{Poisson}\big(r_{jtkl}P_{jtkl}\big) \\
\log\left(r_{jtkl}\right) &= \beta_{0t} + \beta_1 X_{1j} + \beta_2 X_{2k} + \beta_3 X_{3t} + \\
& f\left(x_{tl}\right) + v_t + u_l \\
x_{tl} \mid x_{(t-1)l}, x_{(t-2)l}, \sigma_x^2 &\sim \text{Normal}\left(2x_{(t-1)l} + x_{(t-2)l}, \sigma_x^2\right) \\
v_t \mid v_{t-1}, \sigma_v^2 &\sim \text{Normal}(v_{t-1}, \sigma_v^2) \\
u_l &= \sigma_u^2\left(\sqrt{1-\theta}\gamma_l^\star + \sqrt{\theta}\delta_l^\star\right)
\end{aligned}
$$

Step 2: Decomposition model

Let O_{tk} be number all-cause deaths, L_{tk} the laboratory-confirmed COVID-19-related deaths and E_{tkq} the expected all-cause mortality had the pandemic not occurred, on the t-th week for the k-th group for the q-th sample:

$$O_{tk} \sim \text{Poisson}(\lambda_{tk})$$

$$\lambda_{tk} = \sum_k \beta_{1k} L_{tk} + \sum_k \beta_{2k} E_{tkq} + u_{tk}$$

$$u_{tk} \sim \text{Normal}(0, \sigma_u^2), \text{ with } \sum_{tk} u_{tk} = 0$$

Step 2: Interpretation β_1 & β_2

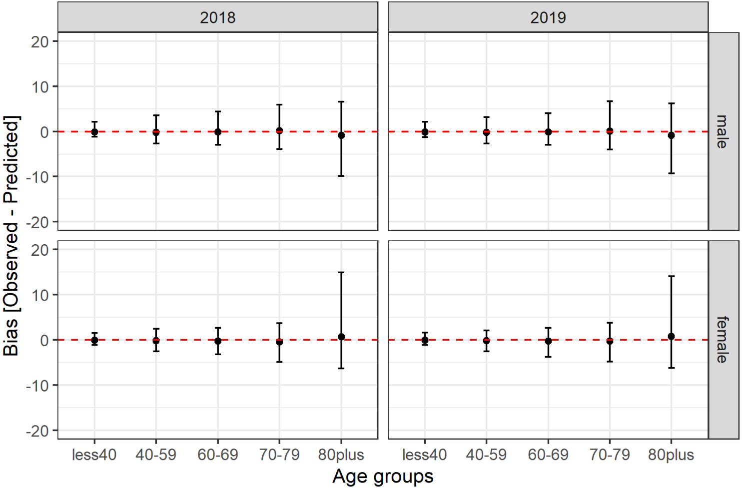
- β_1: # of deaths for each unit increase in lab deaths.
  - **direct effect** of pandemic: deaths attributable to SARS-CoV-2 infections.
  - $\beta_1 = 1$: perfect case ascertainment.
  - $\beta_1 > 1$: number of deaths attributable to SARS-CoV-2 greater than laboratory confirmed deaths
  - $1/\beta_1$: ascertainment proportion.
- β_2: # of all-cause deaths for unit increase in expected.
  - **indirect effect** of pandemic: remaining deaths not attributable to SARS-CoV-2 infections.
  - $\beta_2 = 1$: net effect of pandemic-related changes on death is 0.
  - $\beta_2 < 1$: fewer deaths than expected after removing direct SARS-CoV-2 deaths (i.e. due to protective control measures).

Results

Population results (cross validation)

Model	Coverage	RMSE	mean bias
BASE	0.08	6198	15
OV	0.96	7481	145
OV_INT	0.98	6009	9
VC	0.38	7415	175
VC_OV	0.55	6265	17
VC_OV_INT	0.61	7694	139

Expected model: Cross validation

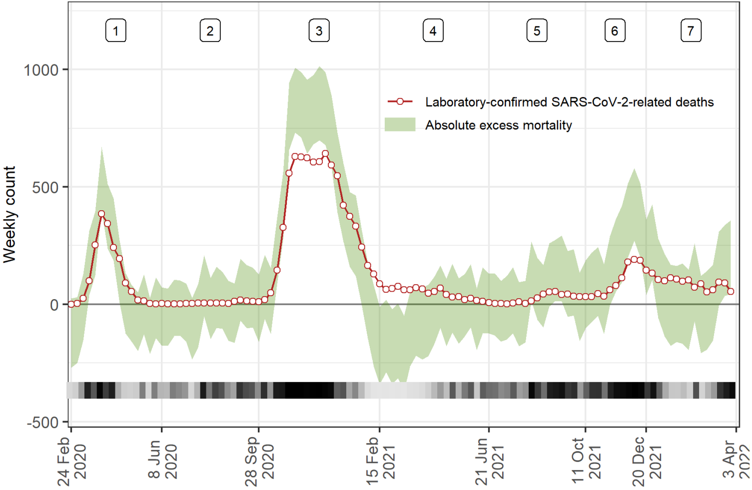


First results

Phase*	Expected	Observed	Excess	Relative excess	Laboratory
1	19,376 (18,767-20,033)	20,791	1,415 (758-2,024)	7% (4-11)	1,725
2	19,180 (18,440-20,042)	19,103	-76 (-939-663)	0% (-5-4)	104
3	27,004 (25,569-28,604)	36,157	9,154 (7,553-10,588)	34% (26-41)	7,652
4	23,386 (22,320-24,834)	22,369	-1,017 (-2,465-49)	-4% (-10-0)	895
5	19,174 (18,284-20,223)	20,007	832 (-216-1,723)	4% (-1-9)	380
6	13,036 (12,298-13,944)	15,105	2,070 (1,161-2,807)	16% (8-23)	956
7	21,370 (20,067-22,894)	22,661	1,291 (-233-2,594)	6% (-1-13)	1,418

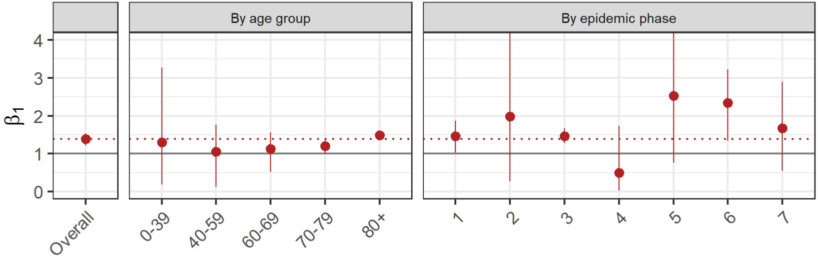
* Phase 1: February 24, 2020 to June 7, 2020, phase 2: June 8, 2020 to September 27, 2020, phase 3: September 28, 2020 to February 14, 2021, phase 4: February 15, 2021 to June 20, 2021, phase 5: June 21, 2021 to October 10, 2021, phase 6: October 11, 2021 to December 19, 2021 and phase 7: December 20, 2021 to April 3, 2022.

Excess and lab deaths alignment



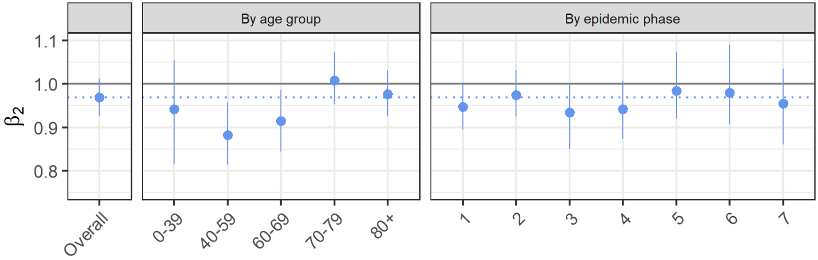
Decomposition model: β_1

- $\beta_1 = 1.38$ (95% CrI 1.22-1.54)
- Ascertainment proportion: 72% (95% CrI 65-82)
- 18,140 (95% CrI 15,962-20,174)
- Higher for older populations and during the larger epidemic waves



Decomposition model: β_2

- $\beta_2 = 0.97$ (95% CrI 0.93-1.01)
- 3% (95% CrI -1-7) fewer all-cause deaths than expected
- 4,406 (95% -1,776-10,700) fewer all-cause deaths than expected
- Younger population most effected, and most prominent during and after the waves



Discussion

Summary of the results/ Take home message

- COVID-19 was directly responsible for $\sim$18,000 deaths although 13,000 reported (primarily in the elderly).
- Incomplete ascertainment in retirement and nursing homes.
- Pandemic may have had an indirect beneficial effect $\sim$4,000 fewer deaths than expected (primarily younger age groups).
- Indirect effects, such as reductions in mobility, road traffic, air pollution and sports activities and/or harvesting effect.

Take home message

Any negative effects of control measures on mortality were offset by the positive effects, raising important implications for the ongoing debate about the appropriateness of COVID-19 control measures.

Questions?

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