The interplay between excess mortality and SARS-CoV-2 laboratory confirmed deaths

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Aims

1. Estimate the excess all-cause mortality in Switzerland in 2020-2021 precisely by age, canton and epidemic phase (with uncertainty)

2. Examine the interplay between excess mortality and laboratory-confirmed SARS-CoV-2-related deaths

Step 1: estimate the excess all-cause mortality

Definition:

- excess mortality = observed mortality - expected mortality
- counter-factual reasoning: how many deaths would have occurred had the pandemic not occurred?

Extrapolate from:

- historical trends in mortality data
- by location, age, sex
- account for changes in population (e.g. ageing)
- account for key covariates (e.g. temperature)

Step 1: estimate the expected mortality

Bayesian spatio-temporal model[1] providing estimates of expected mortality in 2020-2021 from mortality data in 2014-2019:

- by week
- by age group (0-39, 40-59, 60-69, 70-79 and 80+)
- by canton

Adjusting for:

- population trends (extrapolated from data on Dec. 31st 2014-2019)
- temperature
- public holidays

[1] G. Konstantinoudis et al., *Regional excess mortality during the 2020 COVID-19 pandemic in five European countries* (Nature Communications, 2022)

Results: Excess mortality

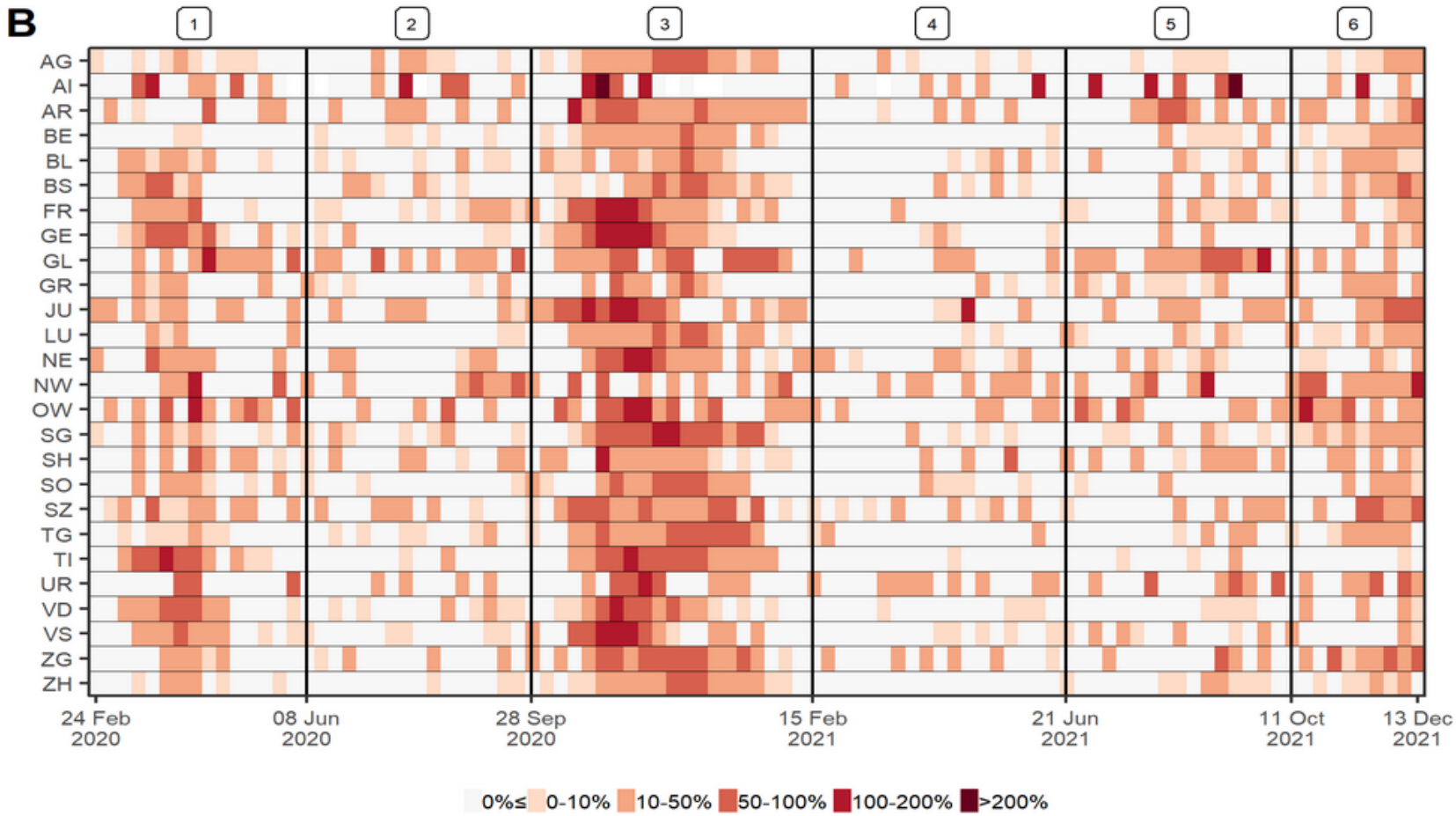


Figure: Weekly excess mortality in Switzerland in 2020-2021 by canton (epidemic phases 1 to 6 as defined by the BAG).

Results: Excess mortality

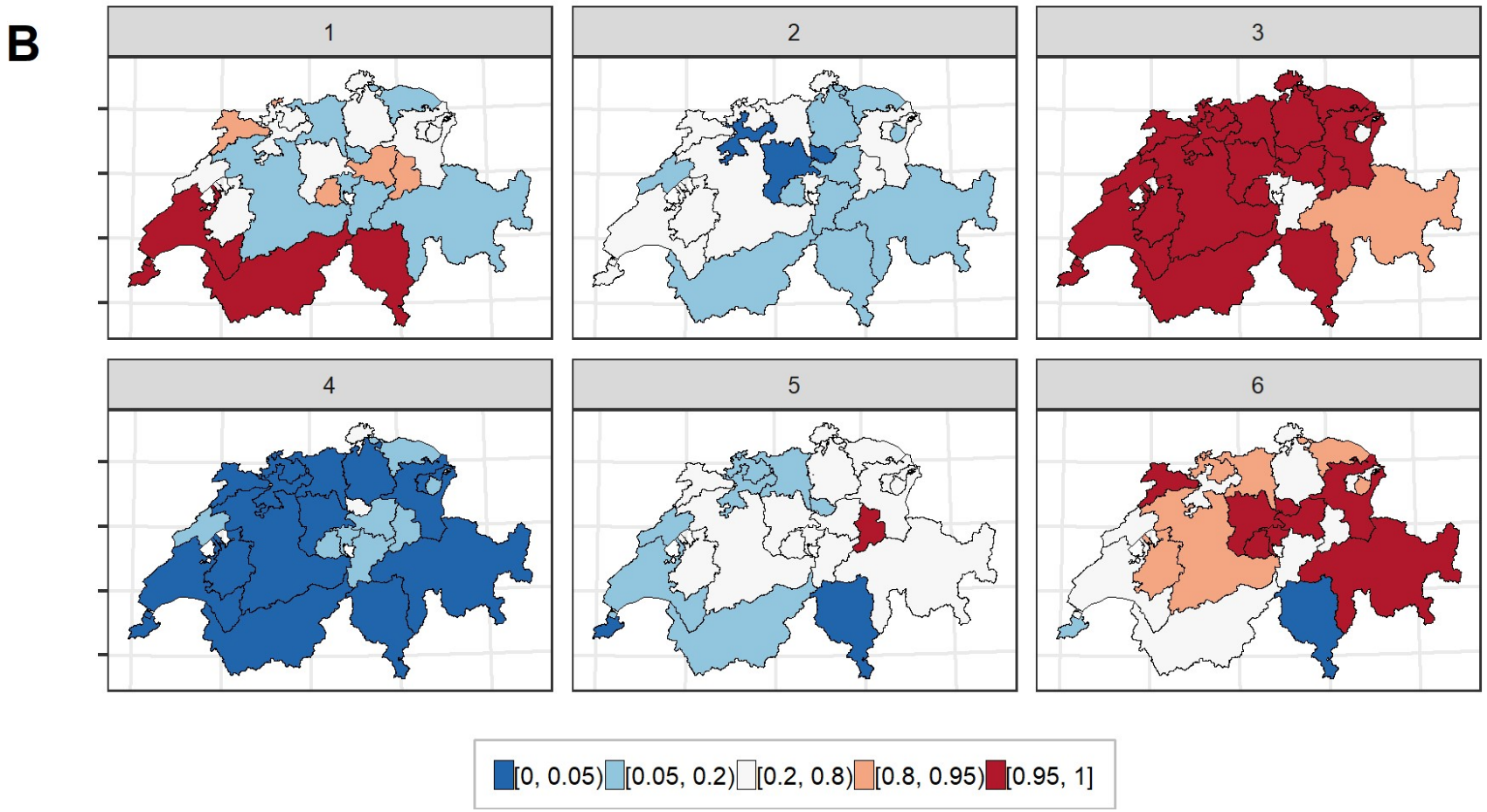


Figure: Probability of excess mortality in Switzerland by canton for each epidemic phase.

Step 2: excess mortality vs. SARS-CoV-2 deaths

Visual comparison between:

- estimated excess all-cause deaths
- laboratory-confirmed SARS-CoV-2-related deaths

Figure: Excess all-cause deaths and laboratory-confirmed SARS-CoV-2-related deaths in Switzerland in 2020-2021 over time.

Step 2: excess mortality vs. SARS-CoV-2 deaths

Statistical approach using modified Poisson regression (no intercept):

$$O_t \sim \text{Poisson}\left(\beta_1 L_t + \beta_2 E_t\right)$$

where:

- O_t is the observed number of all-cause deaths on week t
- L_t is the number of laboratory-confirmed SARS-CoV-2 deaths
- E_t is the expected number of all-cause deaths given historical trends

Step 2: excess mortality vs. SARS-CoV-2 deaths

$$O_t \sim \text{Poisson}\left(\beta_1 L_t + \beta_2 E_t\right)$$

Interpretation: β_1 is the additional number of observed deaths for each unit increase in laboratory-confirmed deaths, controlling for expected deaths:

- if $\beta_1 = 1 \rightarrow$ perfect ascertainment of SARS-CoV-2 deaths
- if $\beta_1 > 1 \rightarrow$ more deaths attributable to SARS-CoV-2 than laboratory-confirmed deaths

$\Rightarrow \beta_1$ measures the direct effect of the pandemic on mortality

$\Rightarrow \beta_1 \times L_t$ is the total number of deaths directly attributable to SARS-CoV-2 infections

$\Rightarrow 1/\beta_1$ corresponds to the ascertainment of SARS-CoV-2-related deaths

Step 2: excess mortality vs. SARS-CoV-2 deaths

$$O_t \sim \text{Poisson}\left(\beta_1 L_t + \beta_2 E_t\right)$$

Interpretation: β_2 is the additional number of observed deaths for each unit increase in the expected number of all-cause deaths, controlling for SARS-CoV-2 deaths:

- if $\beta_2 = 1 \rightarrow$ as many "all-cause-except-SARS-CoV-2" deaths than expected
- if $\beta_2 < 1 \rightarrow$ fewer "all-cause-except-SARS-CoV-2" deaths than expected

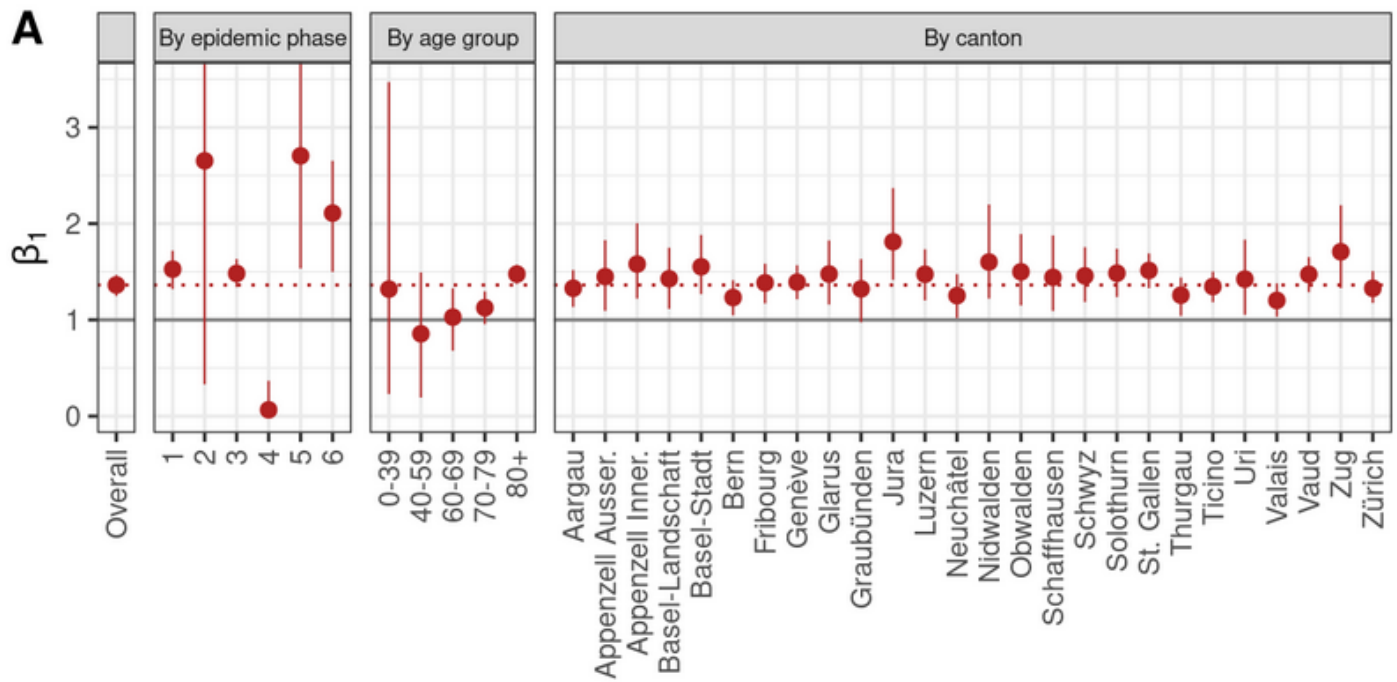
$\Rightarrow \beta_2$ measures the indirect effect of the pandemic on mortality

Result: direct effect

Overall β_1 is estimated to 1.45 (95% CrI: 1.33 to 1.57):

- 33% to 57% more deaths directly attributable to SARS-CoV-2 than confirmed over the whole period
- 64% to 75% ($1/\beta_1$) of deaths directly attributable to SARS-CoV-2 have been ascertained

Estimates by epidemic phase, age group and canton:



Result: direct effect

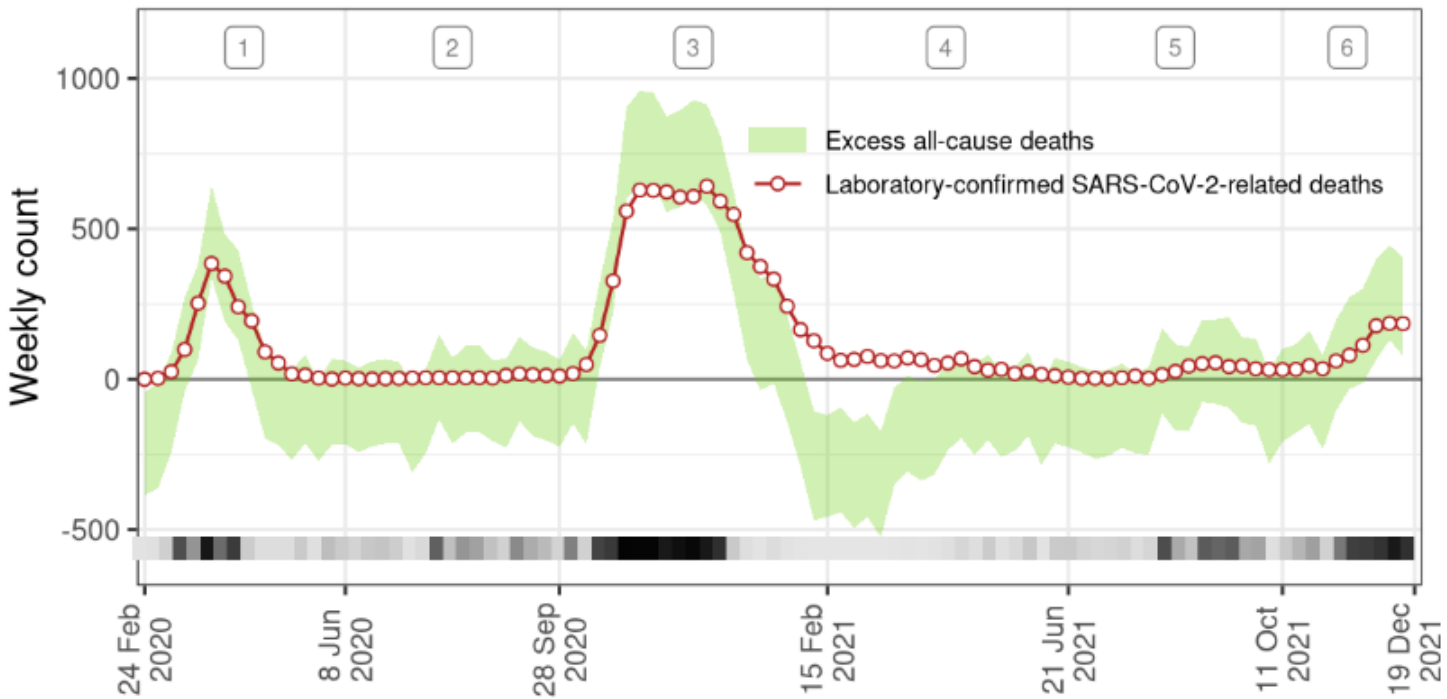


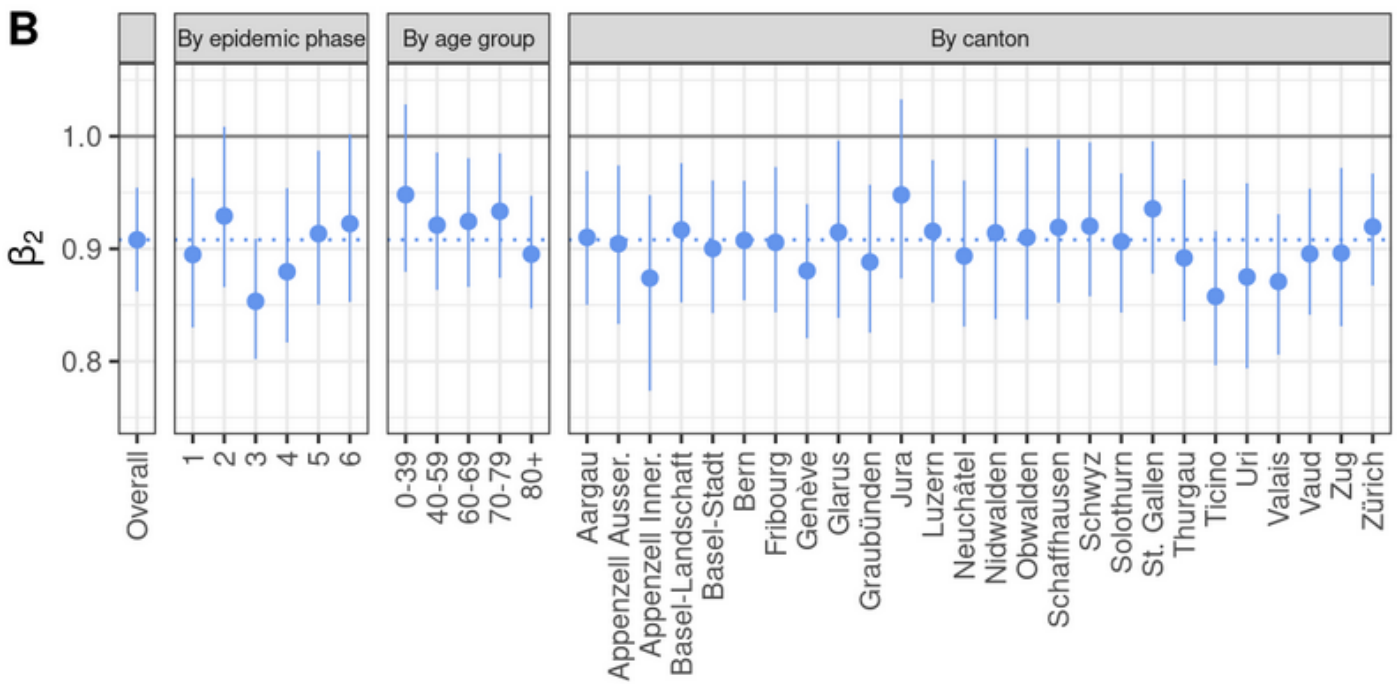
Figure: Excess all-cause deaths and laboratory-confirmed SARS-CoV-2-related deaths in Switzerland in 2020-2021 over time.

Result: indirect effect

Overall β_2 is estimated to 0.91 (95% CrI: 0.86 to 0.96):

- 4% to 14% fewer "all-cause-except-SARS-CoV-2" deaths than expected
- multiple indistinguishable causes: mortality displacement, protective effect of control measures (traffic, influenza...)

Estimates by epidemic phase, age group and canton:



Result: indirect effect

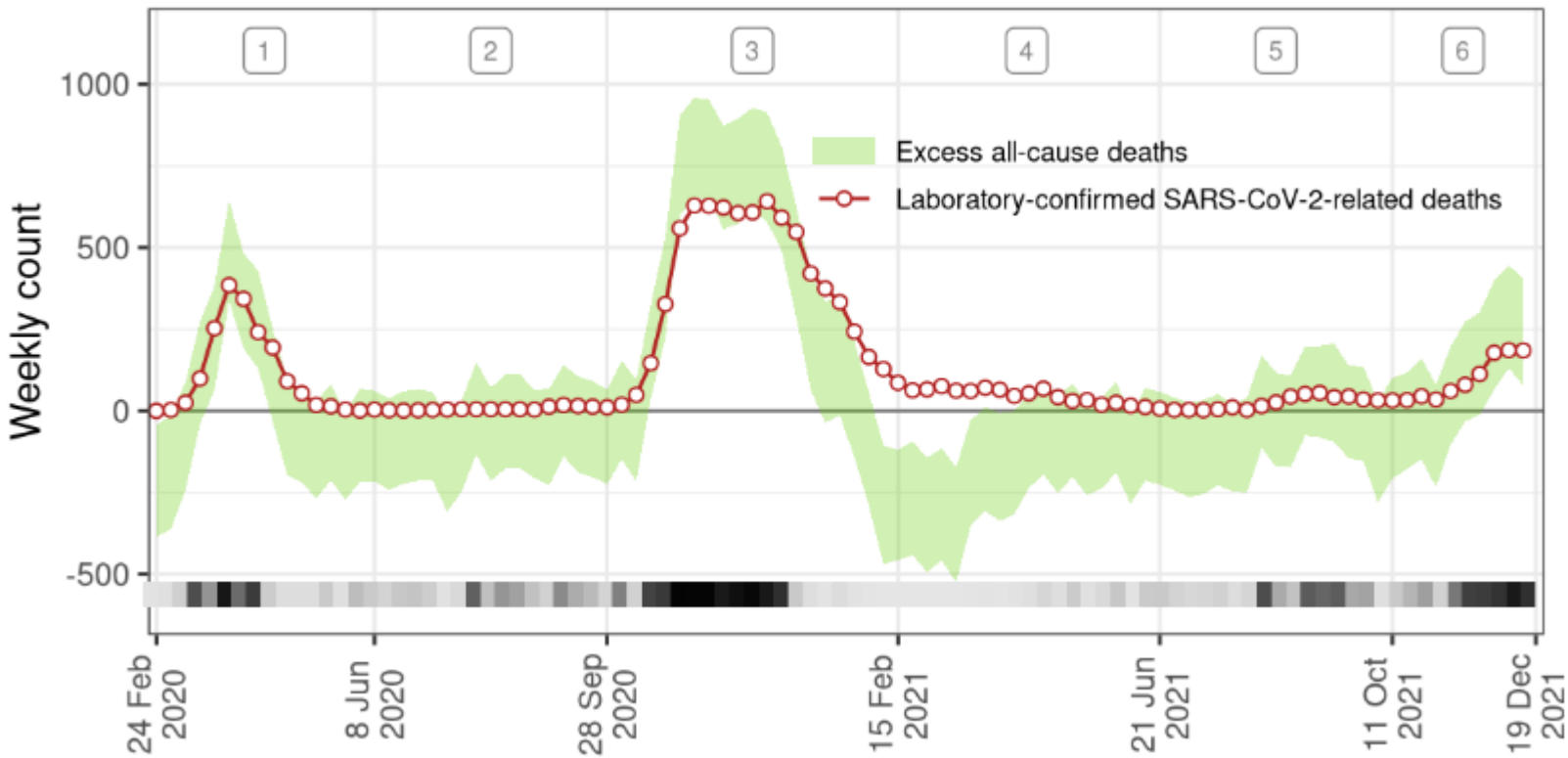


Figure: Excess all-cause deaths and laboratory-confirmed SARS-CoV-2-related deaths in Switzerland in 2020-2021 over time.

Conclusions

New insights:

- new approach to distinguish between deaths attributable to SARS-CoV-2 infections and deaths from other causes
- quantification of the ascertainment of SARS-CoV-2-related deaths
- quantification of the indirect effects of the SARS-CoV-2 pandemic on mortality (displacement + protective effects of control measures)
- consistent effects by age group (80+)
- homogeneous across cantons

Limitations:

- the estimate β_2 relies on the accuracy of the estimated expected mortality (underestimation?)
- simple linear model: interpretation results with caution