

Online Resource 7. Sensitivity analyses for counterfactual estimation of pandemic excess mortality

Article: Age–period–cohort effects on suicide mortality in Andalusia, Spain (2000–2024): demographic masking and sustained pandemic excess

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This Online Resource presents sensitivity analyses for the counterfactual estimation of pandemic-associated excess suicide mortality described in the main text. The robustness of the excess estimate was evaluated by varying two key analytical choices: (1) the training window used to fit the pre-pandemic trend model, and (2) the functional form of the projection (log-linear vs generalised additive model). All models were fit to pre-pandemic data and projected onto 2020–2024 to generate expected rates under the counterfactual scenario of trend continuation.

1. Counterfactual model specifications

Four counterfactual specifications were estimated for each sex stratum:

(a) **Main model (2000–2019):** A log-linear trend model ($\ln[\text{rate}] = \alpha + \beta \times \text{year}$) fit to the full 20-year pre-pandemic series. This is the primary model reported in the main text.

(b) **Reduced window (2005–2019):** The same log-linear specification fit to a 15-year window, excluding the earliest years when rates were higher, to assess sensitivity to the choice of baseline period.

(c) **Last joinpoint segment (2014–2019):** A log-linear model fit only to the final pre-pandemic segment identified by joinpoint regression. This captures the most recent trend acceleration and provides an upper-bound estimate of excess under the assumption that the steepest decline would have continued.

(d) **GAM with penalised cubic spline (2000–2019):** A generalised additive model allowing for non-linear trends. This tests whether the log-linear assumption materially affects the excess estimate.

2. Sensitivity of excess mortality estimates

Table S8a. Counterfactual excess suicide mortality under four model specifications, Andalusia 2020–2024

Model	Training window	n	EAPC (%) (95% CI)	R ²	Observed	Expected	Excess	O/E (95% CI)	p
Both sexes									
Main (log-linear)	2000–19	20	–0.93 (–1.44, –0.43)	0.422	4,134	3,351	+783 (+23.4%)	1.23 (1.20–1.27)	< 0.001
Reduced window	2005–19	15	–1.23 (–2.06, –0.38)	0.383	4,134	3,270	+864 (+26.4%)	1.26 (1.23–1.30)	< 0.001
Last JP segment	2014–19	6	–3.18 (–5.23, –1.09)	0.687	4,134	2,917	+1,217 (+41.7%)	1.42 (1.37–1.46)	< 0.001
GAM (cubic spline)	2000–19	20	—	0.455	4,134	3,283	+851 (+25.9%)	1.26 (1.22–1.30)	< 0.001
Men									
Main (log-linear)	2000–19	20	–1.07 (–1.62, –0.53)	0.451	3,169	2,547	+622 (+24.4%)	1.24 (1.20–1.29)	< 0.001
Reduced window	2005–19	15	–1.31 (–2.24, –0.38)	0.369	3,169	2,496	+673 (+26.9%)	1.27 (1.23–1.31)	< 0.001
Last JP segment	2014–19	6	–4.12 (–6.24, –1.94)	0.771	3,169	2,117	+1,052 (+49.7%)	1.50 (1.45–1.55)	< 0.001
GAM (cubic spline)	2000–19	20	—	0.529	3,169	2,395	+774 (+32.3%)	1.32 (1.28–1.37)	< 0.001
Women									
Main (log-linear)	2000–19	20	–0.52 (–1.25, +0.22)	0.097	965	791	+175 (+22.1%)	1.22 (1.14–1.30)	< 0.001

Model	Training window	n	EAPC (%) (95% CI)	R ²	Observed	Expected	Excess	O/E (95% CI)	p
Reduced window	2005–19	15	-0.91 (-2.12, +0.32)	0.139	965	765	+200 (+26.1%)	1.26 (1.18–1.34)	< 0.001
Last JP segment	2014–19	6	+0.11 (-4.85, +5.32)	0.000	965	814	+151 (+18.6%)	1.19 (1.11–1.26)	< 0.001
GAM (cubic spline)	2000–19	20	—	0.097	965	791	+175 (+22.1%)	1.22 (1.14–1.30)	< 0.001

EAPC: estimated annual percentage change in age-standardised rates during the training window. O/E: ratio of observed to expected deaths; 95% CI computed using Poisson exact method. GAM: generalised additive model with penalised cubic spline (effective degrees of freedom: 2.0–2.7); EAPC not applicable. JP: joinpoint. All p-values test the null hypothesis of no excess (O/E = 1.00).

All four specifications yielded statistically significant excess mortality for both sexes combined, men, and women (all $p < 0.001$). For both sexes combined, the O/E ratio ranged from 1.23 (main model) to 1.42 (last joinpoint segment), corresponding to an excess of 783 to 1,217 deaths. The three models with training windows of 15–20 years converged on a narrow range (O/E = 1.23–1.26), while the joinpoint segment model, which projects the steepest pre-pandemic decline, provided an upper-bound estimate (O/E = 1.42). This convergence across specifications confirms that the estimated excess is robust to the choice of training window and functional form.

Sex-stratified results showed a consistent pattern. For men, the O/E range was 1.24–1.50 across specifications, with the GAM model yielding a somewhat higher estimate (O/E = 1.32) than the main log-linear model (O/E = 1.24), suggesting mild non-linearity in the pre-pandemic trend. For women, all models converged on a narrower range (O/E = 1.19–1.26), with the joinpoint segment model yielding the lowest estimate (O/E = 1.19) because the pre-pandemic trend in women was nearly flat (EAPC = +0.11%, $p = 0.96$).

3. Year-by-year observed versus expected deaths

Table S8b. Observed and expected suicide deaths by year and sex under the main counterfactual model (log-linear, 2000–2019), Andalusia 2020–2024

Year	Observed	Expected	95% PI	Excess	O/E	Within PI?
Both sexes						
2020	793	677	580–791	+116	1.17	No*
2021	849	673	575–787	+176	1.26	No*
2022	830	668	570–784	+162	1.24	No*
2023	815	668	568–785	+147	1.22	No*
2024	847	665	565–784	+182	1.27	No*
2020–2024	4,134	3,351	—	+783	1.23	—
Men						
2020	576	516	437–611	+60	1.12	Yes
2021	661	512	432–607	+149	1.29	No*
2022	651	508	428–604	+143	1.28	No*
2023	631	507	426–604	+124	1.25	No*
2024	650	504	422–602	+146	1.29	No*
2020–2024	3,169	2,547	—	+622	1.24	—
Women						
2020	217	158	126–198	+59	1.37	No*
2021	188	158	126–199	+30	1.19	Yes
2022	179	158	125–199	+21	1.14	Yes
2023	184	158	125–200	+26	1.16	Yes
2024	197	158	125–201	+39	1.24	Yes
2020–2024	965	791	—	+175	1.22	—

PI: 95% prediction interval from the log-linear model. O/E: observed-to-expected ratio. * Observed deaths exceeded the upper bound of the 95% PI. For both sexes combined, observed deaths exceeded the prediction interval in all five years. For men, all years except 2020 exceeded the interval. For women, only 2020 exceeded the interval; the remaining years fell within the wider PI reflecting greater uncertainty in the female trend model ($R^2 = 0.097$).

The year-by-year analysis revealed that the excess was not confined to the acute pandemic phase (2020) but persisted across all five years. For both sexes combined, the O/E ratio ranged from 1.17 (2020) to 1.27 (2024), with no evidence of reversion to the pre-pandemic trend (slope of O/E = +0.016/year, $p = 0.250$). A notable sex-differential pattern emerged in 2020: women showed the highest relative excess in the initial year (O/E = 1.37), while men showed a lower initial excess (O/E = 1.12) that subsequently increased. This divergence may reflect differential timing of the psychosocial impact by sex.

4. Graphical comparison of counterfactual projections

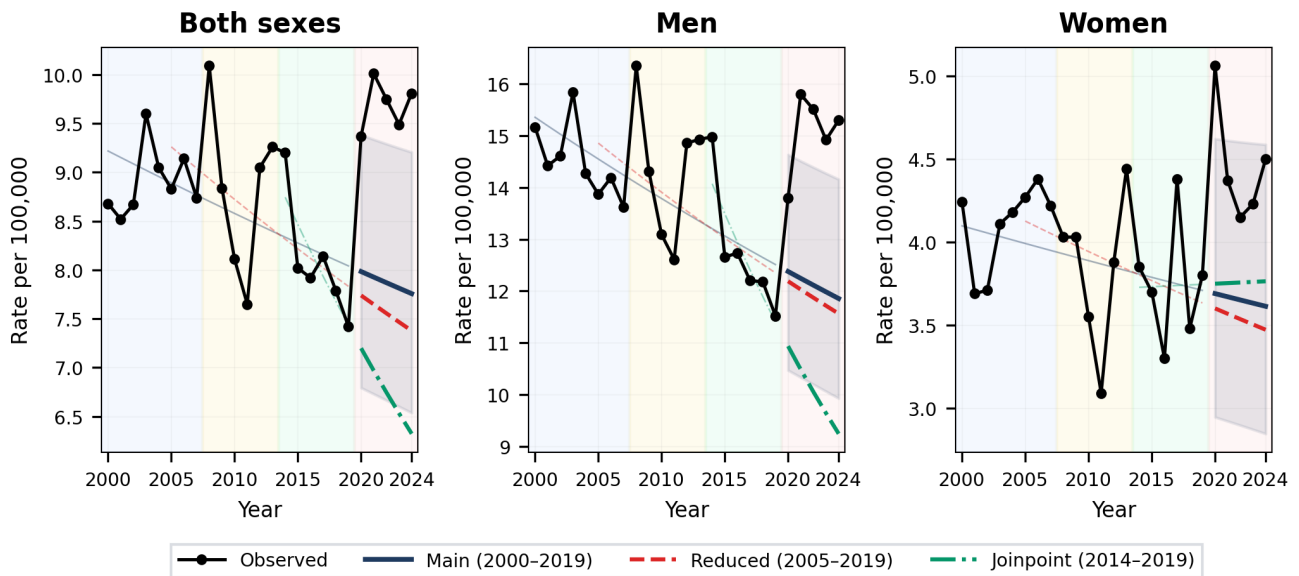


Figure S17. Observed suicide rates versus counterfactual projections under three log-linear training windows, by sex. Solid black line with markers: observed crude rates. Coloured lines: projected expected rates under the main model (2000–2019, solid dark blue), reduced window (2005–2019, dashed red), and last joinpoint segment (2014–2019, dash-dotted green). Thin lines during the training period show the model fit; thick lines show the projection onto 2020–2024. Shaded grey band: 95% prediction interval for the main model. Background bands indicate historical periods (blue: pre-crisis; yellow: recession; green: recovery; red: pandemic). All three models project rates below the observed values during 2020–2024, confirming significant excess mortality regardless of the training window choice.

Summary

The sensitivity analyses confirm the robustness of the estimated pandemic-associated excess in suicide mortality. Across four counterfactual specifications, the O/E ratio for both sexes combined ranged from 1.23 to 1.42, with the three long-window models converging on 1.23–1.26. All models yielded $p < 0.001$. The excess persisted across all five years of the pandemic period (2020–2024), with no evidence of reversion to pre-pandemic levels. These findings collectively indicate that the estimated 783 excess deaths (+23.4%) under the main model represent a conservative and robust estimate of the pandemic-associated impact on suicide mortality in Andalusia.