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Supporting Information

Supplementary material

This appendix was part of the submitted manuscript and has been peer reviewed.
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Appendix to: Egger SJ, David M, Weber MF, et al. Trends in adolescent smoking prevalence before and after the emergence of vaping in Australia; an interrupted time series analysis, 1999–2023. *Med J Aust* 2025; doi: 10.5694/mja2.70000.

Supplementary and sensitivity analyses

Methods

In supplementary analysis using gender-specific data, we added main effects terms for gender (male/female) and interaction terms between gender and the background-trend and vaping-trend variables into the logistic models. Gender-specific results are presented for smoking outcomes where there was a significant interaction between gender and vaping-trend (i.e. where the relative change in the observed trend at the 'change-year' differed by gender) (Figure 1).

We also performed five sets of sensitivity analyses as follows:

1. To assess whether our findings were overly dependent on selecting 2010 as the change-year, we conducted sensitivity analyses; we refitted the primary segmented regression models but with varying the change years from 2008 to 2014 (Table 1).

2. To assess whether our findings were impacted by cigarette affordability (Figure 2), we refitted the primary segmented regression models adjusting for the log of factory-made cigarette affordability (i.e. the log of the number of factory-made cigarettes that could be purchased by 12-17-year-old Australian secondary school students based on their average available money from 1999 to 2022–2023), and the relative affordability difference between roll-your-own and factory-made cigarettes (calculated as the difference in their log affordability), and an interaction term between these variables. This approach aimed to control for the affordability of factory-made cigarettes and the potential for substitution to the cheaper roll-your-own option (Figure 3) to assess whether cigarette affordability was a confounder of the observed changes in smoking trends. We did not perform this sensitivity analysis for daily smoking (i.e. 14-15-year-olds) because cigarette affordability data was only available for 12-17-year-olds.[1]

3. We conducted a sensitivity analysis excluding the 2022–2023 data, leaving 2017 as the final year of data (but still extrapolating smoothed prevalence estimates to 2022–2023 for comparative purposes). We conducted this sensitivity analysis for two reasons: (1) to account for the potential distorting influence of the COVID-19 pandemic on our findings; and (2) to account for the potential influence of recent increases in illicit tobacco activity (this is because Australian Border Force seizure volumes and consumer awareness of unbranded tobacco were relatively stable until about 2019, but both measures began to rise from around 2019–20,[2] suggesting possible increases in the availability of cheaper illicit cigarettes that could distort smoking prevalence estimates in the 2022–2023 data).

4. To assess the impact of using observed sample sizes (N_{year}) in the primary segmented logistic regression models, we re-ran the models assuming the sample size for each year was reduced to one-sixth of its original value (i.e. $N_{year}/6$). This approach simulates a survey design effect of 6—a value beyond what is typically observed in large national school-based surveys with complex sampling designs,[3] which commonly range between 1.5 and 5—and was used to test the robustness of our findings to potential overestimation of precision due to an unaccounted-for design effect.

5. To address the possibility that model-based standard errors may understate uncertainty in the presence of residual autocorrelation, we re-ran the primary segmented logistic regression models using heteroskedasticity- and autocorrelation-consistent (HAC) standard errors for all 5 smoking outcomes.

Results

Significant interactions were observed between gender and the relative change in the observed smoking trend for ever smoking (Table 2) with excesses of 59 (95% CI, 49-68) more male and 85 (95% CI, 75-94) more female students per 1000 in 2022–2023 (Figure 1), and past year smoking (Table 2) with excesses of 43 (95% CI, 35-42) more male and 62 (95% CI, 54-70) more female students per 1000 in 2022–2023 (Figure 2).

In the sensitivity analysis varying the change-year from 2008 to 2014, the choice of change-year did not appreciably change our findings (Table 1). In the sensitivity analysis that controlled for the affordability of factory-made cigarettes and the relative affordability difference between roll-your-own and factory-made cigarettes for 12-17-year-olds, the 2022–2023 excess numbers were similar to those obtained in the main analysis (Figure 4). In the sensitivity analysis excluding the 2022–2023 data, findings were consistent with those from the main analysis, suggesting that the observed changes in trends from 2010 were not driven by COVID-19 pandemic-related disruptions or possible recent increases in illicit cigarette availability (Figure 5). In the sensitivity analysis assuming a survey design effect of 6 (i.e. using N/6 as the sample size for each year), findings were materially unchanged, with confidence intervals only marginally wider (Table 3). In the sensitivity analysis, applying HAC standard errors across all 5 smoking outcomes also had no material impact, with all findings remaining consistent and only small increases in confidence interval widths (Table 4).

References

1. Bayly M, Scollo MM. Figure 13.5.3, Chapter 13.5: How affordable are cigarettes in Australia? In: Greenhalgh EM, Scollo MM, Winstanley MH, editors. Tobacco in Australia: Facts and issues. Melbourne: Cancer Council Victoria; 2024. Available from: https://www.tobaccoinaustralia.org.au/chapter-13-taxation/13-5-how-affordable-are-cigarettes-in-australia. Viewed Apr 2025.
2. Cho A, Bayly M and Scollo MM. 13A.5 Estimates of illicit cigarette trade in Australia. In Greenhalgh EM, Scollo MM and Winstanley MH, editors. Tobacco in Australia: Facts and issues. Melbourne: Cancer Council Victoria; 2025. Available from: from https://www.tobaccoinaustralia.org.au/chapter-13-taxation/indepth-13a-avoidance-and-evasion-of-taxes-on-tobacco-products/13a-5-estimates-of-illicit-cigarette-trade-in-australia. Viewed Apr 2025.
3. Phillips GW. Impact of design effects in large-scale district and state assessments. Appl Meas Educ 2015; 28: 33–47.

Table 1: Odds ratios for changes in the rate of decline in smoking at change-years ranging from 2008 to 2014

Model change-year	Ever smoking (12-17 years)		Past year smoking (12-17 years)		Past month smoking (12-17 years)		Past week smoking (12-17 years)		Daily smoking (14-15 years)	
	$OR_{\beta 2}$ (95% CI)^	p-value^^	$OR_{\beta 2}$ (95% CI)^	p-value^^	$OR_{\beta 2}$ (95% CI)^	p-value^^	$OR_{\beta 2}$ (95% CI)^	p-value^^	$OR_{\beta 2}$ (95% CI)^	p-value^^
2008	1.07 (1.06, 1.08)	<0.001	1.07 (1.06, 1.08)	<0.001	1.06 (1.05, 1.07)	<0.001	1.06 (1.05, 1.07)	<0.001	1.12 (1.09, 1.15)	<0.001
2009	1.07 (1.06, 1.07)	<0.001	1.07 (1.06, 1.07)	<0.001	1.06 (1.05, 1.07)	<0.001	1.06 (1.05, 1.07)	<0.001	1.11 (1.08, 1.14)	<0.001
2010	1.07 (1.06, 1.08)	<0.001	1.07 (1.06, 1.07)	<0.001	1.06 (1.05, 1.07)	<0.001	1.06 (1.04, 1.07)	<0.001	1.12 (1.08, 1.15)	<0.001
2011	1.07 (1.06, 1.08)	<0.001	1.06 (1.06, 1.07)	<0.001	1.05 (1.04, 1.06)	<0.001	1.05 (1.04, 1.06)	<0.001	1.12 (1.07, 1.17)	<0.001
2012	1.07 (1.06, 1.07)	<0.001	1.06 (1.05, 1.06)	<0.001	1.05 (1.04, 1.06)	<0.001	1.04 (1.03, 1.05)	<0.001	1.11 (1.05, 1.18)	<0.001
2013	1.07 (1.07, 1.08)	<0.001	1.06 (1.05, 1.07)	<0.001	1.05 (1.03, 1.06)	<0.001	1.04 (1.03, 1.06)	<0.001	1.13 (1.06, 1.19)	<0.001
2014	1.08 (1.07, 1.09)	<0.001	1.06 (1.05, 1.07)	<0.001	1.04 (1.03, 1.05)	<0.001	1.04 (1.03, 1.05)	<0.001	1.14 (1.07, 1.21)	<0.001

Shaded cells correspond to model shown in Figures 1 and 2 with change-year=2010.
^ $OR_{\beta 2}$ are odds ratios for changes in the rates of decline in smoking at the change-year, with $OR_{\beta 2}>1$ indicating a slowing in the rate of decline and $OR_{\beta 2}<1$ indicating an acceleration in the rate of decline.
^^ p-values are for test of $OR_{\beta 2} = 1.00$.

Table 2: p-values for tests of autocorrelation and interaction between gender and change in observed smoking trend for each smoking outcome

	Breusch–Godfrey test for first order autocorrelation		Interaction between gender and change in observed smoking trend	
Smoking outcome variable	$\chi^2(1)$^	**p-value**	$\chi^2(1)$^	**p-value**
Ever smoking (12-17 years)	2.73	0.099	12.82	<0.001
Past year smoking (12-17 years)	0.34	0.560	6.86	0.009
Past month smoking (12-17 years)	1.60	0.206	0.76	0.384
Past week smoking (12-17 years)	0.55	0.460	0.02	0.877
Daily smoking (14-15 years)	5.34	0.021	n/a^^	n/a^^

^ Test statistics are Chi-square distributed with 1 degree of freedom ($\chi^2(1)$). For the Breusch–Godfrey test, this assesses first-order autocorrelation in residuals. For the gender interaction, the statistic is the squared Wald Z for the β coefficient of the interaction between gender and post-change trend. Corresponding p-values test the null hypothesis that the statistic equals zero.
^^ Gender-specific results were not available for daily smoking.

Table 3: Segmented logistic regression estimates from sensitivity analysis assuming a survey design effect of 6 (N/6 adjustment)

Smoking behaviour	p-value^	$OR_{\beta 2}$ (95% CI)	O_{23} (95% CI)	B_{23} (95% CI)	E_{23} (95% CI)
Ever smoking (12-17yrs)	<0.001	1.07 (1.05, 1.09)	13.2% (12.1, 14.4)	5.8% (5.3-6.4)	74 (58, 90)
Past year smoking (12-17yrs)	<0.001	1.07 (1.05, 1.09)	9.7% (8.8, 10.8)	4.3% (3.9-4.8)	54 (40, 68)
Past month smoking (12-17yrs)	<0.001	1.06 (1.03, 1.08)	4.9% (4.2, 5.6)	2.4% (2.1-2.8)	25 (14, 34)
Past week smoking (12-17yrs)	<0.001	1.05 (1.03, 1.08)	3.1% (2.5, 3.7)	1.5% (1.3-1.8)	16 (8, 23)
Daily smoking (14-15yrs)	<0.001	1.12 (1.08, 1.16)	0.9% (0.7, 1.2)	0.2% (0.1-0.3)	7 (4, 10)

^ p-values are for test of $OR_{\beta 2} = 1.00$.

Table 4: Segmented logistic regression estimates from sensitivity analysis using heteroskedasticity and autocorrelation-consistent (HAC) standard errors for all smoking outcomes

Smoking behaviour	p-value^	$OR_{\beta 2}$ (95% CI)	O_{23} (95% CI)	B_{23} (95% CI)	E_{23} (95% CI)
Ever smoking (12-17yrs)	<0.001	1.07 (1.06, 1.08)	13.2% (12.5, 13.8)	5.8% (5.5-6.1)	74 (63, 85)
Past year smoking (12-17yrs)	<0.001	1.07 (1.04, 1.09)	9.7% (8.2, 11.5)	4.3% (3.6-5.2)	54 (33, 76)
Past month smoking (12-17yrs)	0.004	1.06 (1.02, 1.10)	4.9% (3.5, 6.7)	2.4% (1.7-3.3)	25 (6, 44)
Past week smoking (12-17yrs)	0.007	1.06 (1.01, 1.10)	3.1% (2.2, 4.1)	1.5% (1.1-2.1)	16 (3, 28)
Daily smoking (14-15yrs)	<0.001	1.12 (1.08, 1.15)	0.9% (0.7, 1.2)	0.2% (0.2-0.3)	7 (4, 9)

^ p-values are for test of $OR_{\beta 2} = 1.00$.

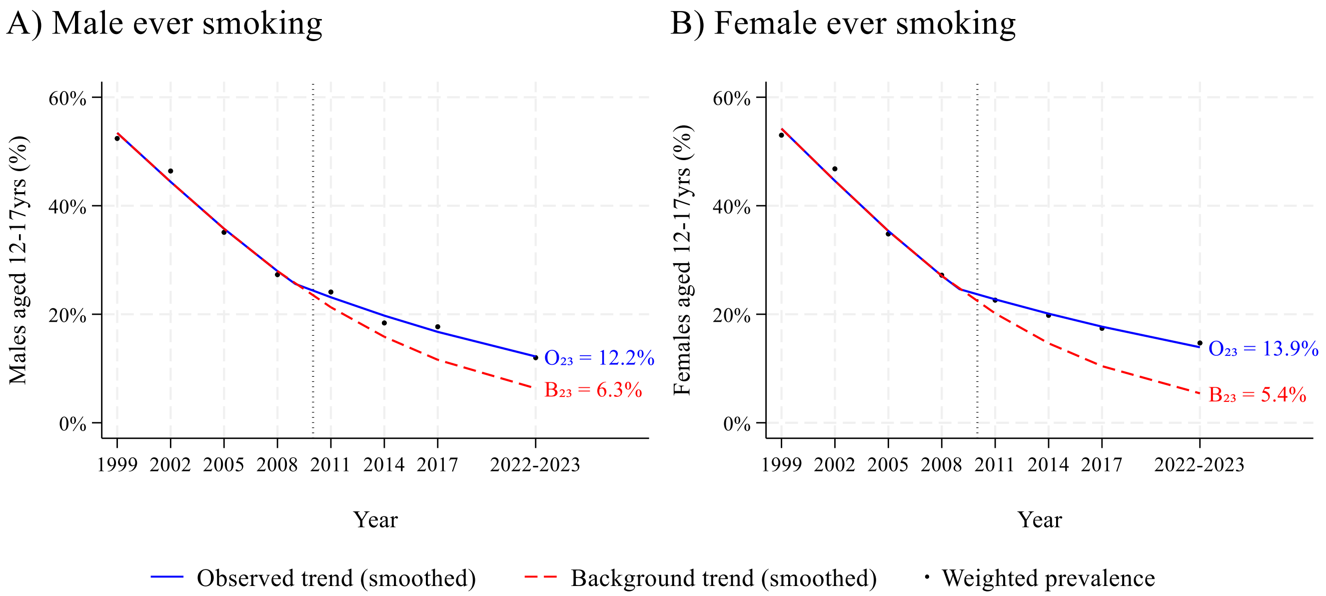

Figure 1: Gender-specific ever smoking estimates corresponding to a significant interaction between gender (male/female) and change in observed ever smoking trend (p<0.001)

Statistical results corresponding to panels A–B:

A) Male ever smoking; $p<0.001$ for $OR_{\beta2}=1.05$ v 1.00, $O_{23}=12.2\%$ (95% CI, 11.6-12.9), $B_{23}=6.3\%$ (95% CI, 6.0-6.7), $E_{23}=59$ (95% CI, 49-68)

B) Female ever smoking; $p<0.001$ for $OR_{\beta2}=1.08$ v 1.00, $O_{23}=13.9\%$ (95% CI, 13.2-14.6), $B_{23}=5.4\%$ (95% CI, 5.1-5.7), $E_{23}=85$ (95% CI, 75-94)

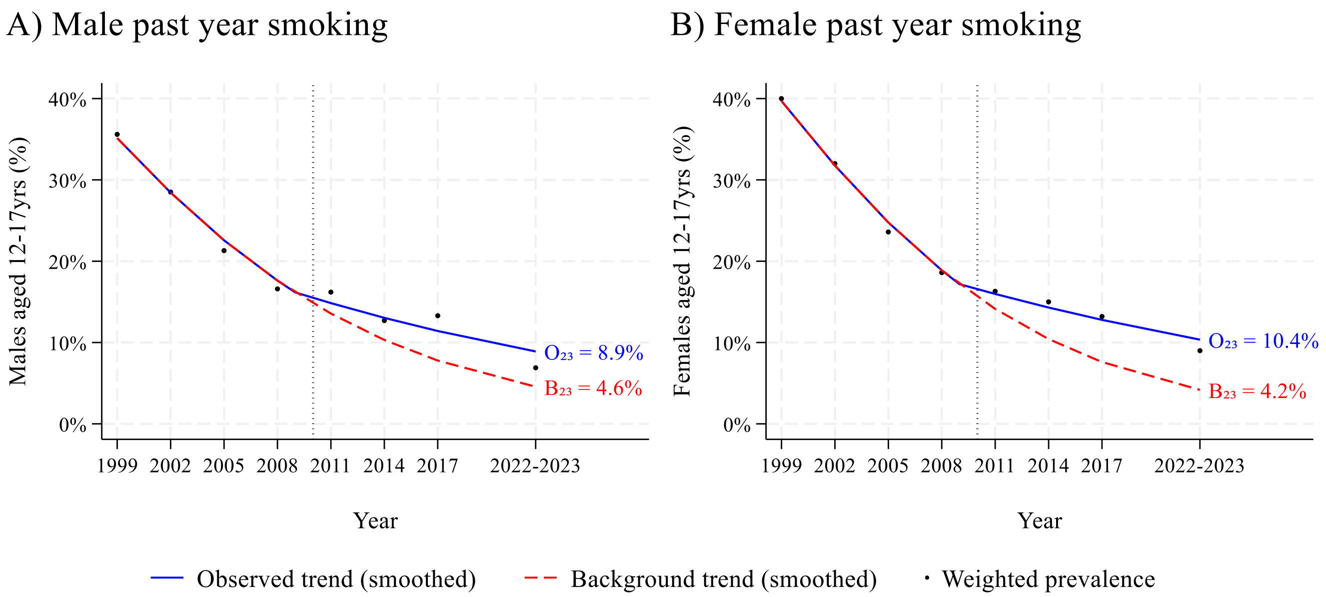

Figure 2: Gender-specific past year smoking estimates corresponding to a significant interaction between gender (male/female) and change in observed past year smoking trend (p=0.009)

Statistical results corresponding to panels A–B:

A) Male past year smoking; $p<0.001$ for $OR_{\beta2}=1.05$ v 1.00, $O_{23}=8.9\%$ (95% CI, 8.4-9.5), $B_{23}=4.6\%$ (95% CI, 4.3-4.9), $E_{23}=43$ (95% CI, 35-52)

B) Female past year smoking; $p<0.001$ for $OR_{\beta2}=1.07$ v 1.00, $O_{23}=10.4\%$ (95% CI, 9.8-11.0), $B_{23}=4.2\%$ (95% CI, 3.9-4.4), $E_{23}=62$ (95% CI, 54-70)

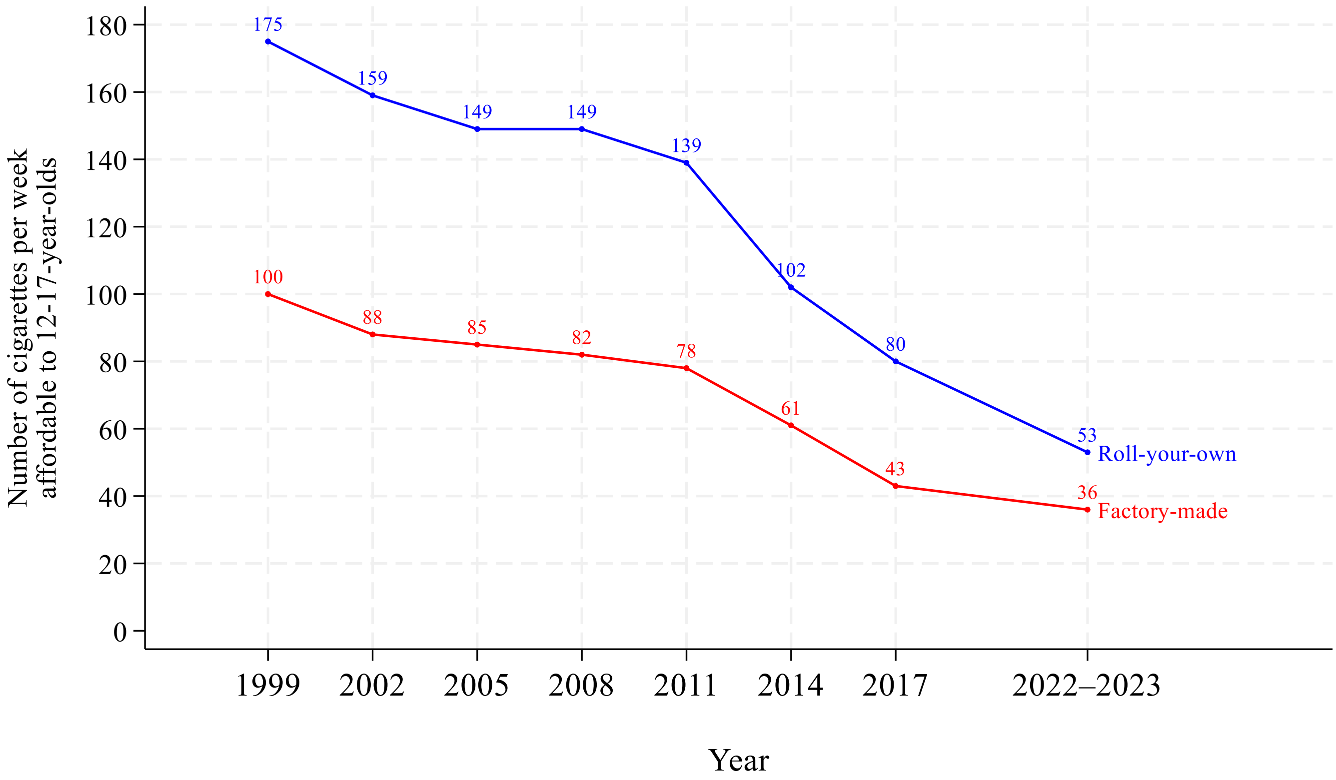

Figure 3: Affordability of cigarettes; number of roll-your-own and factory-made and tobacco cigarettes that could be purchased by 12-17-year-old Australian secondary school students based on average available money per week

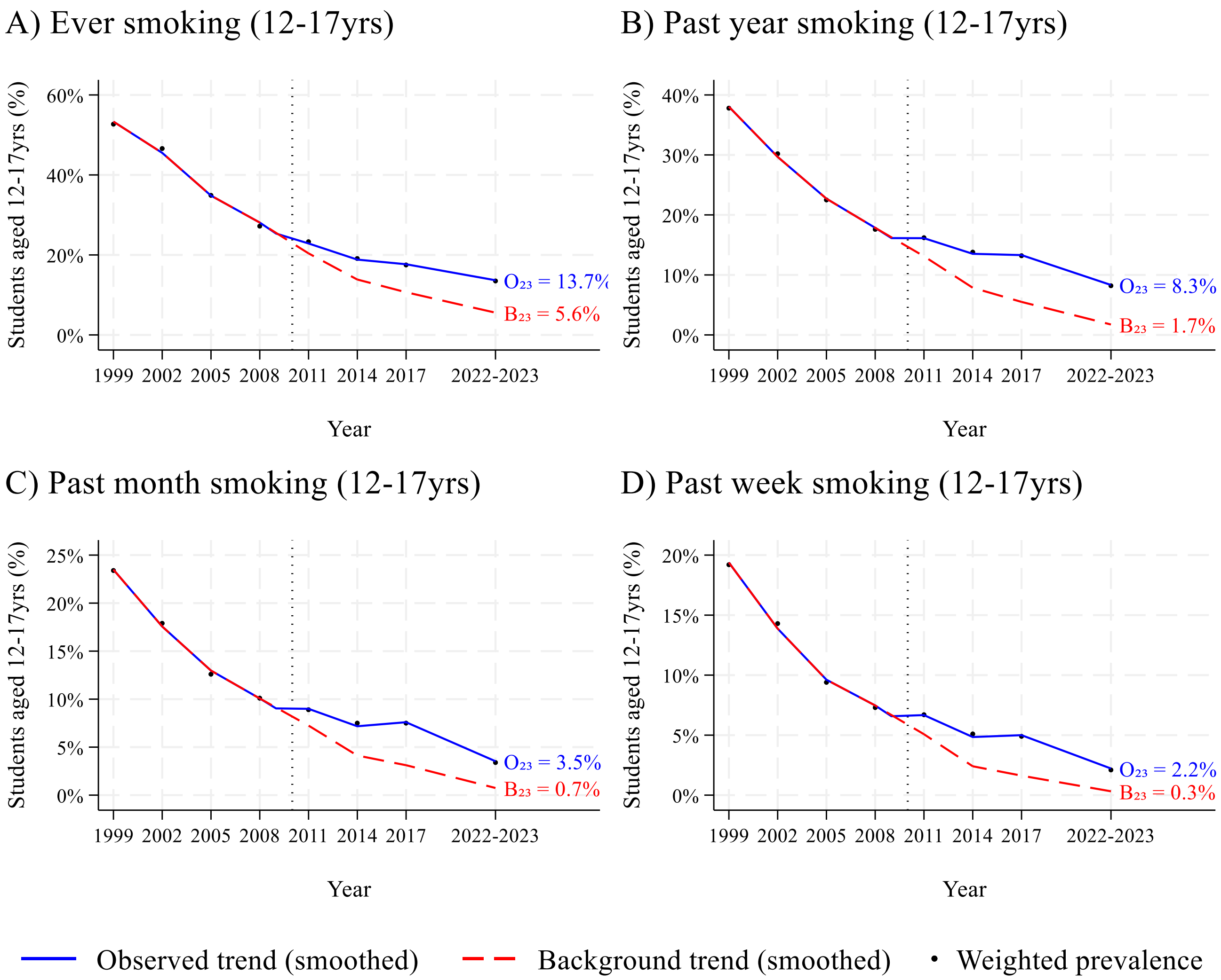

Figure 4: Observed and background trends for 12-17-year-old students estimated from segmented logistic regression models adjusted for cigarette affordability^, and weighted prevalence for A) ever smoking (12-17yrs), B) past year smoking (12-17yrs), C) past month smoking (12-17yrs), and D) past week smoking (12-17yrs)

^ Adjusted for the log of the number of factory-made cigarettes that could be purchased by 12-17-year-old Australian secondary school students based on their average available money from 1999 to 2022–2023, the relative affordability difference between roll-your-own and factory-made cigarettes (i.e. the difference in their log affordability) and the interaction between these variables.

Statistical results corresponding to panels A–D:

A) Ever smoking; $p<0.001$ for $OR_{\beta 2}$=1.08 v 1.00, O_{23}=13.7% (95% CI, 13.0-14.3), B_{23}=5.6% (95% CI, 5.3-5.9), E_{23}=81 (95% CI, 67-95)
B) Past year smoking; $p<0.001$ for $OR_{\beta 2}$=1.13 v 1.00, O_{23}=8.3% (95% CI, 7.8-8.9), B_{23}=1.7% (95% CI, 1.6-1.9), E_{23}=66 (95% CI, 59-73)
C) Past month smoking; $p<0.001$ for $OR_{\beta 2}$=1.12 v 1.00, O_{23}=3.5% (95% CI, 3.2-3.9), B_{23}=0.7% (95% CI, 0.7-0.8), E_{23}=28 (95% CI, 24-32)
D) Past week smoking; $p<0.001$ for $OR_{\beta 2}$=1.16 v 1.00, O_{23}=2.2% (95% CI, 2.0-2.5), B_{23}=0.3% (95% CI, 0.3-0.4), E_{23}=19 (95% CI, 16-22)

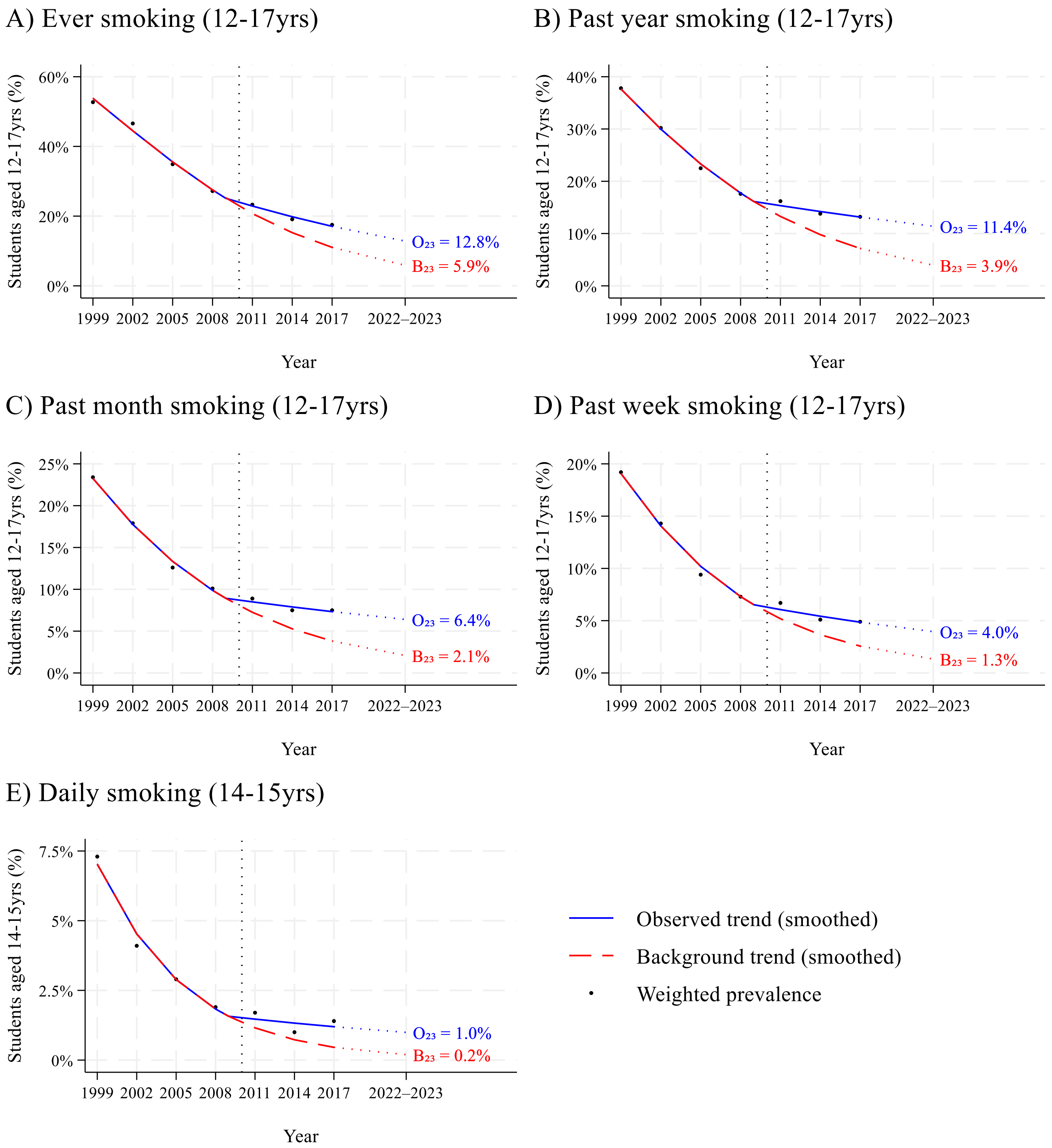

Figure 5: Observed and background trends for 12-17-year-old students estimated from segmented logistic regression models excluding the 2022-23 data, leaving 2017 as the final year of data, to account for potential COVID-19-related distortions and/or recent increases in illicit cigarette availability on for A) ever smoking (12-17yrs), B) past year smoking (12-17yrs), C) past month smoking (12-17yrs), D) past week smoking (12-17yrs), and E) daily smoking (14-15yrs); smoothed prevalence estimates were extrapolated to 2022–2023 for comparative purposes

Statistical results corresponding to panels A–E:

A) Ever smoking; $p<0.001$ for $OR_{\beta 2}$=1.07 v 1.00, O_{23}=12.8% (95% CI, 12.2-13.5), B_{23}=5.9% (95% CI, 5.6-6.2), E_{23}=69 (95% CI, 61-78)
B) Past year smoking; $p<0.001$ for $OR_{\beta 2}$=1.09 v 1.00, O_{23}=11.4% (95% CI, 10.8-12.1), B_{23}=3.9% (95% CI, 3.7-4.2), E_{23}=75 (95% CI, 66-83)
C) Past month smoking; $p<0.001$ for $OR_{\beta 2}$=1.09 v 1.00, O_{23}=6.4% (95% CI, 5.9-6.9), B_{23}=2.1% (95% CI, 1.9-2.3), E_{23}=43 (95% CI, 37-49)
D) Past week smoking; $p<0.001$ for $OR_{\beta 2}$=1.09 v 1.00, O_{23}=4.0% (95% CI, 3.6-4.4), B_{23}=1.3% (95% CI, 1.2-1.5), E_{23}=27 (95% CI, 22-31)
E) Daily smoking: $p<0.001$ for $OR_{\beta 2}$=1.13 v 1.00, O_{23}=1.0% (95% CI, 0.6-1.6), B_{23}=0.2% (95% CI, 0.1-0.3), E_{23}=8 (95% CI, 3-13)