

**Distinguishing legalization from
commercialization**

**Rapid retail cannabis rollout and adolescent
tobacco and cannabis use in the United States**



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Cannabis and tobacco use in adolescents

- Since 2012, 24 states and DC have legalized cannabis for adults 21 and over; 23 have licensed stores open.
- Past-month use among high-school students in our panel, 2023:
 - Cannabis 14–16% (19–23% in 2011)
 - E-cigarettes 14–17% (peak of 23–26% in 2019)
 - Cigarettes 3–4% (13–17% in 2011)

Cannabis in adolescence

- Earlier initiation is a risk factor for problem cannabis use; so is more frequent use (NASEM 2017: substantial evidence).
- Effects on the developing brain are the subject of the Surgeon General's 2019 advisory.

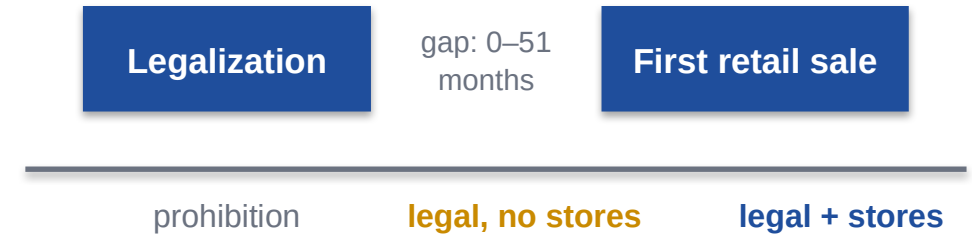
Cannabis and nicotine

- Adolescents who vape have about four times the odds of using cannabis (meta-analysis of 21 studies, Chadi et al. 2019).
- In the 2023 state YRBS, 61% of students who vaped in the past month also used cannabis (Dave et al. 2025).
- Policy studies find the two to be complements or unrelated.

Two policies, usually coded as one

- Three separate state decisions: whether to legalize, whether to permit retail sales, and how quickly to implement them.
- Evaluations of youth use usually code every post-legalization year as treated — or, when estimating retail effects, treat the legal-but-no-stores period as untreated.
- Either way the legal-no-stores window is pooled — with retail years, or with prohibition — and few studies estimate it on its own.

One state's policy history



Conventional coding (RCL+): one treated period



This paper: the windows estimated separately



Pathways by policy stage

After legalization, before stores

- Perceived risk and peer norms shift
- Parental norms shift
- Social supply and an illicit market meet demand without age checks
- Home cultivation where permitted
- Lower penalties and less enforcement

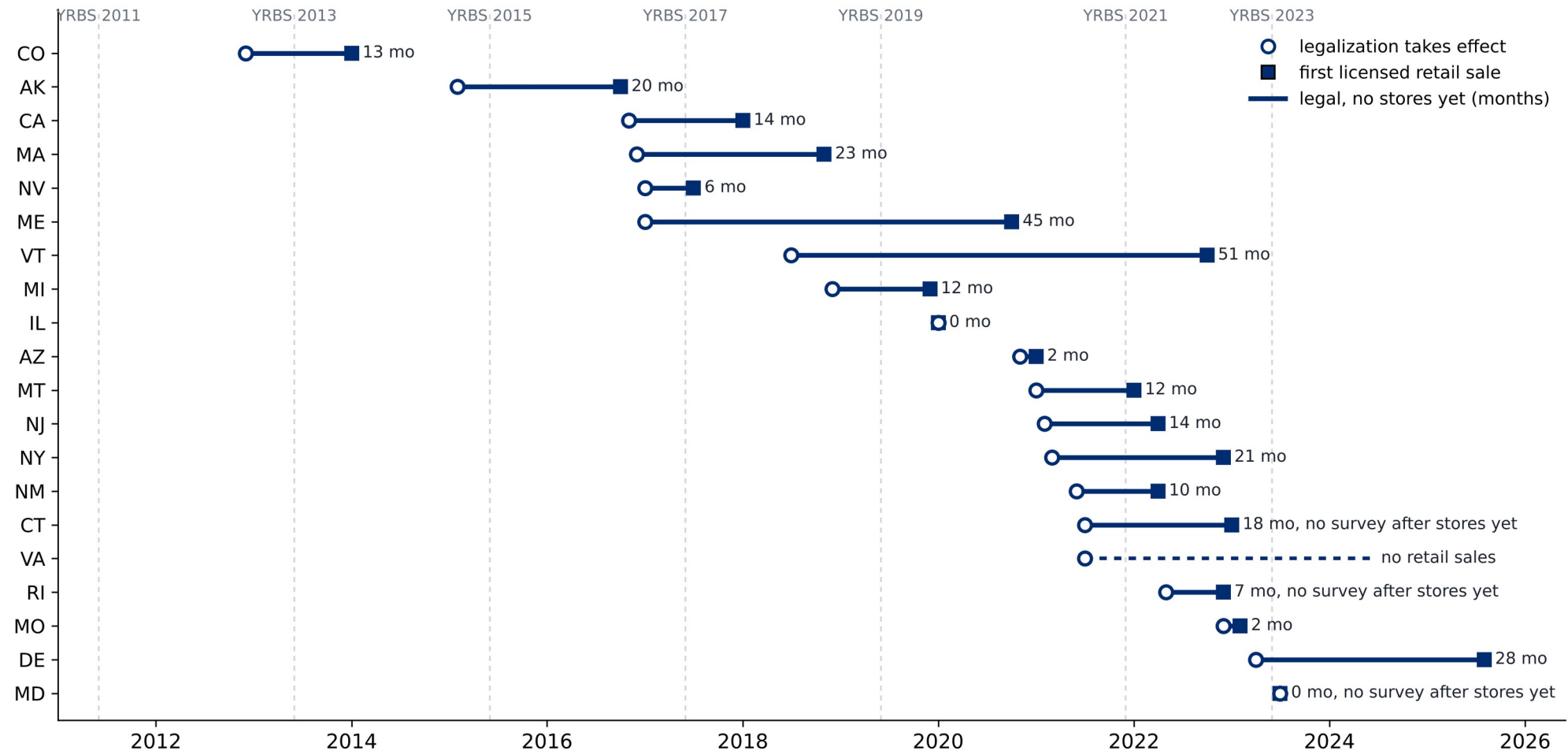
Once licensed retail opens

- Prices, availability, retail density and marketing
- Age verification
- Compliance inspections
- Possible displacement of the illicit market

Why tobacco outcomes belong in a cannabis evaluation

- **Co-use**
- **Shared access channels**
- **Shared use norms**

Legalization and first retail sale, by state



Twelve of the nineteen legalizing states with retail opened stores within 14 months; seven took 18 to 51 months.

What earlier studies find

Policy coded as	Study and data	Finding (past-month cannabis use unless noted)
Every year after legalization	Anderson et al. 2024 state YRBS 1993–2021	–1.4 pp; national YRBS: no change
	Coley et al. 2024 state YRBS 2011–2021	Cannabis –0.3 times a month; alcohol –0.2 days; e-cigarettes fall with years since the law; cigarettes unchanged
	Coley et al. 2021 state YRBS 1999–2017	Any use unchanged; users use less often; e-cigarette use more likely; cigarettes and alcohol unchanged
	Hollingsworth et al. 2022 NSDUH 2001–2017, ages 12–17	Past-year use +10% (about +1.5 pp)
	Cerdá et al. 2020 NSDUH 2008–2016, ages 12–17	No change in use; past-year use disorder up
	Montgomery et al. 2022 NSDUH 2008–2019, ages 12–20	No change in first use or prevalence
	Weinberger et al. 2022 NSDUH 2004–2017, ages 12–17	Co-use, cigarette-only and cannabis-only use all less likely
Stores open	Anderson et al. 2024 sales allowed (same data)	–2.2 to –2.6 pp (state YRBS)
	Coley et al. 2024 first store open (same data)	Cannabis: fewer users, but users use more often. Alcohol and cigarettes unchanged; e-cigarette days –0.7
	Hollingsworth et al. 2022 first dispensary open (same data)	Adds nothing for adolescents
	Marinello 2025 NSDUH 2002–2019, ages 12–17, five states	Past-year use +1.5 to +1.9 pp
Meta-analysis	Pawar et al. 2024 30 studies, adolescents and young adults	Adolescents: odds ratio 1.04, not significant; 1.09 in post-2008 studies, about one point

Research question

How does adolescent substance use respond to cannabis legalization — to the law alone, and to the opening of licensed stores?

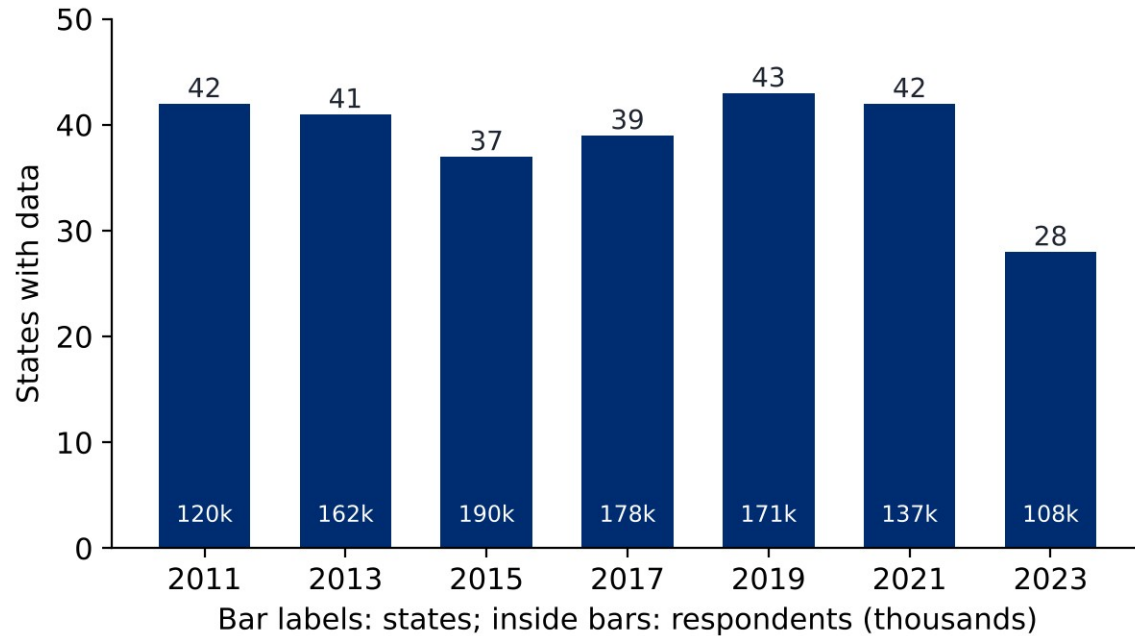
- **1** Does adolescent cannabis use change when a state legalizes, and again when stores open — and does the conventional coding, which pools the two, get it right?
- **2** Does the policy spill over to tobacco — cigarettes, e-cigarettes, dual and polysubstance use — and does intensity among those who still use change?

What is new here

- 1 Mutually exclusive policy windows
- 2 A within-state decomposition: the first legal year vs. the opening of stores
- 3 Tobacco, e-cigarette and co-use outcomes in the same windows, with age and race/ethnicity heterogeneity and intensity among users
- 4 Data through 2023: four more states with stores open (MT, NJ, NM, MO), a second post-retail wave for IL and MI, and a post-COVID wave

Data

State Youth Risk Behavior Surveys, 2011–2023



- A maximum-coverage build of the state YRBS: the combined datasets assembled to include every state-year available, 2011–2023 (seven biennial waves).
- 46 states, 272 state-year cells, 1.1 million high-school respondents.
- E-cigarette items begin in 2015.

Outcomes

Past-30-day prevalence (survey-weighted state-year means)

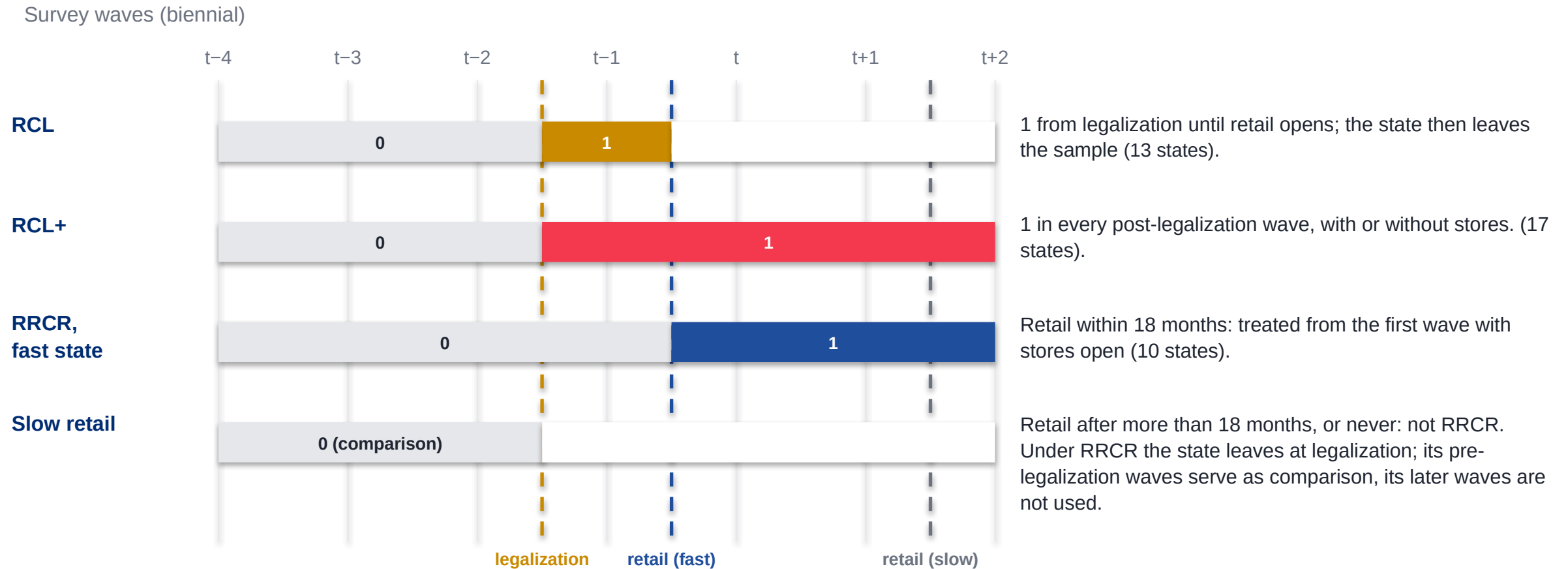
- Cannabis
- Cigarettes
- E-cigarettes (2015–2023)
- Polysubstance: two or more of cannabis, e-cigarettes, cigarettes (2015–2023)
- Dual use: cannabis and cigarettes together (2011–2023)

Intensity, among past-30-day users

- Heavy: 20+ days (cigarettes, e-cigarettes); 20+ times (cannabis)
- Daily: all 30 days (cigarettes, e-cigarettes); 40+ times (cannabis)

Empirical approach

Three ways to code one policy history: RCL, RCL+ and RRCR



"RRCR, legal baseline": RRCR restricted to the six states whose wave before stores is already legal (stores open vs. legal without stores).

Who is in the sample, and when a state leaves it

	2011	2013	2015	2017	2019	2021	2023
CO (2017 cohort)	pre			retail	retail	retail	
CA (2019 cohort)			pre	legal, no retail	retail <i>no cigarette item</i>		
NV (2019 cohort)		pre	pre	legal, no retail	retail	retail	retail
AZ (2021 cohort)	pre	pre	pre	pre	pre	retail	
IL (2021 cohort)	pre	pre	pre	pre	pre	retail	retail
MI (2021 cohort)	pre	pre	pre	pre	legal, no retail	retail	retail
MO (2023 cohort)		pre	pre	pre	pre	pre	retail
MT (2023 cohort)	pre	pre	pre	pre	pre	legal, no retail	retail
NJ (2023 cohort)	pre	pre			pre	legal, no retail	retail
NM (2023 cohort)	pre	pre	pre	pre	pre	legal, no retail	retail

pre-legalization (untreated)
 retail sales open (treated)
 no YRBS data
 legalized, no retail yet (kept as untreated)

Under RRCR (main)

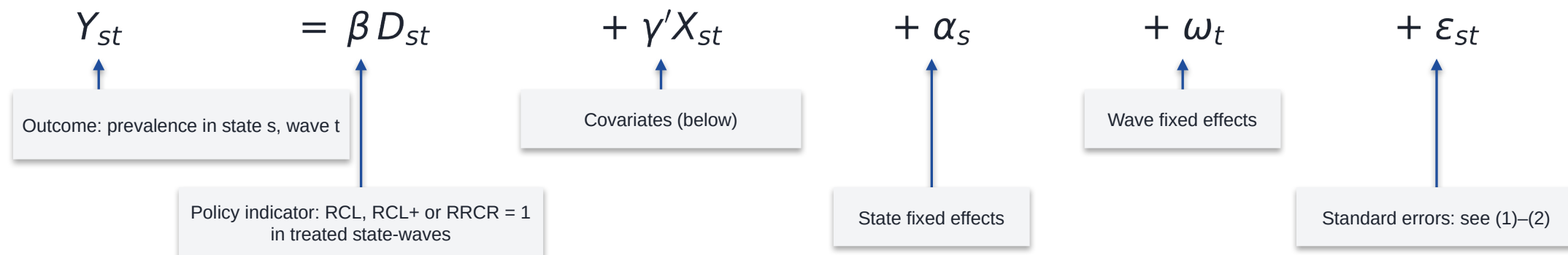
- **Comparison:** the 26 never-legalized states, every wave.
- **RRCR states (10):** all waves before the stores are pre-period, including a legal-no-stores wave where there is one; treated from the first wave with stores open. Colorado has no wave just before its stores and identifies nothing: nine states carry the estimates.
- **Other legalizers (10):** pre-legalization waves stay in as comparison; the state leaves the sample at legalization.

Under the other codings

- **RCL:** a legalizer is treated in its legal-no-stores waves and leaves when its stores open (13 states identify).
- **RCL+:** treated from legalization on, stores or not; nothing leaves (17 states).

Estimation

Two-way fixed effects



Tobacco and e-cigarettes

- Cigarette excise tax; e-cigarette excise tax; harmonized e-cigarette tax (Cotti et al.)
- 100% smoke-free restaurant laws: cigarettes; e-cigarettes
- Flavored e-cigarette sales restrictions; Tobacco 21

Alcohol and cannabis

- Beer excise tax
- Medical cannabis law in effect
- Cannabis decriminalization in effect

Economy and pandemic

- Unemployment rate
- COVID-19 activity-limitations index (Ruhm 2024), nonzero only in the 2021 wave

Standard errors: (1) clustered by state (46 clusters) in every table; (2) wild cluster bootstrap p for the regression estimators.

Staggered difference-in-differences (Callaway and Sant'Anna 2021)

With staggered adoption, TWFE uses already-treated states as controls for later cohorts and averages every earlier wave into the baseline; this estimator does neither.

- **Comparison:** the never-legalized states, every wave (never-treated cells).
- **Cohort:** the states whose stores first opened before the same survey wave; each cohort is compared with the never-treated states from its own last wave before the stores.
- **Aggregation:** the post-retail cohort-by-wave effects averaged into the overall effect, cohorts weighted by their treated state-years; the event study reports them by waves since retail.
- **Covariates:** none in the main estimates.

Key identifying assumption

- Parallel trends: Absent retail rollout, the treated cohorts and the never-legalized states would have moved in parallel.
 - Pre-trend test: are the pre-period event-study estimates jointly zero?
 - Event-study plot: no single pre-period estimate is significant (RRCR, cannabis).
- No anticipation.

Heterogeneity and sensitivity

Heterogeneity

- By sex (boys, girls)
- By age group (14–16; 17–18+)
- By race/ethnicity (White, Black, Hispanic); subgroup cells under 50 respondents dropped
- Intensity among users: daily and heavy, all students and by subgroup

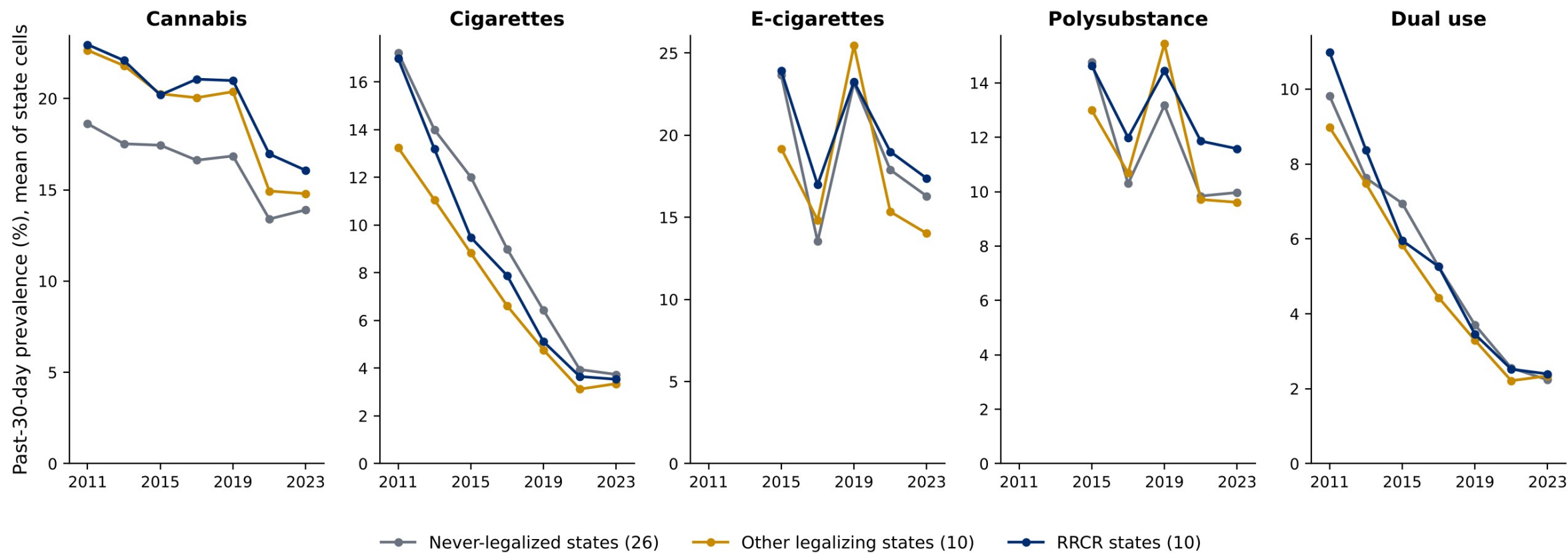
Sensitivity

- Gap rule at 12 and 24 months
- Not-yet-treated comparison
- Drop 2023.
- Callaway–Sant'Anna with the core 6 and with all 12 covariates
- Stacked DiD: each state's own 2×2 from its last pre-legalization survey, so the legal year and the stores step are measured on the same states
- Leave-one-out: each state dropped in turn

Questions or comments so far?

Results

Descriptive statistics: past-30-day prevalence by wave and group



Cannabis policy and youth cannabis prevalence: TWFE and Callaway–Sant'Anna

Coding	(1) TWFE, state and year effects only	(5) TWFE, all 12 covariates	Callaway–Sant'Anna, never-treated (main)	Callaway–Sant'Anna, not-yet-treated	Pre-treatment mean (%)	N state-years (states)
RCL: legal, no stores (13 states)	−0.46 (0.80)	−0.10 (0.70)	−0.82 (0.80)	−0.95 (0.79)	21.5	246 (46)
RCL+: all years after legalization (17)	−0.47 (0.70) [.476]	+0.25 (0.61) [.674]	−1.62* (0.75)	−1.81* (0.74)	21.3	270 (46)
RRCR: stores open within 18 months (10)	−0.87 (0.95) [.332]	−0.23 (1.04) [.815]	−2.07* (0.87)	−2.11* (0.87)	21.2	253 (46)
RRCR, legal baseline: stores open vs. legal without stores (6)	−1.66 (1.25) [.182]	−1.05 (1.25) [.417]	−2.09+ (1.17)	−2.10+ (1.16)	21.5	230 (42)

Percentage points; SE clustered by state in parentheses; [] wild cluster bootstrap p; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$; grey: pre-trend test rejects at 5%.

Cannabis policy and youth substance use: five outcomes under the four codings

Outcome	Pre-treatment mean (%)	RCL	RCL+	RRCR (main)	RRCR, legal baseline
Cannabis	21.2	−0.82 (0.80)	−1.62* (0.75)	−2.07* (0.87)	−2.09+ (1.17)
Cigarettes	10.2	+0.34 (0.56)	+0.91 (0.61)	+0.10 (0.35)	−0.32 (0.43)
E-cigarettes	22.1	+0.43 (1.51)	+0.88 (1.31)	+0.20 (1.48)	−3.53* (1.65)
Polysubstance	14.3	+0.14 (0.90)	+0.55 (0.79)	+0.12 (0.81)	−1.80* (0.87)
Dual use	6.6	−0.12 (0.40)	−0.10 (0.35)	−0.30 (0.35)	−0.40 (0.31)

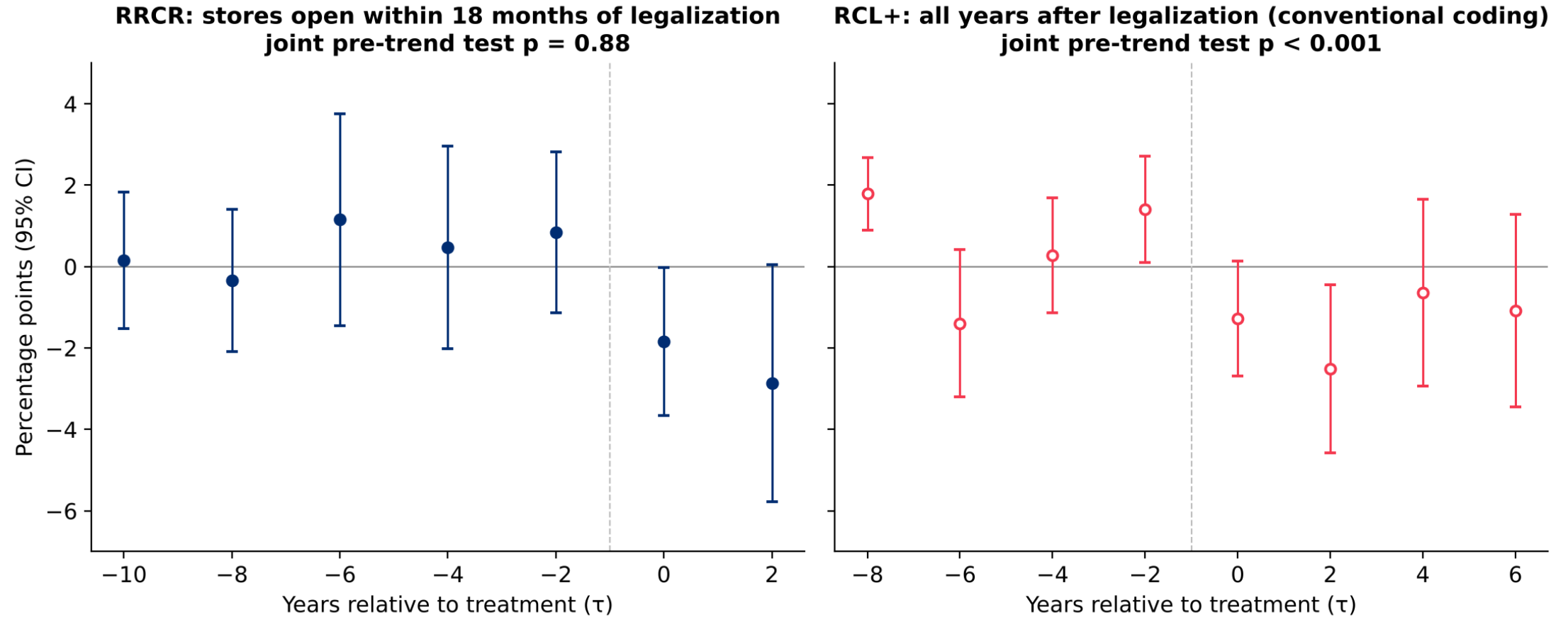
Percentage points; SE clustered by state in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$; grey: pre-trend test rejects at 5%.

Sensitivity to the gap rule: 12, 18 and 24 months

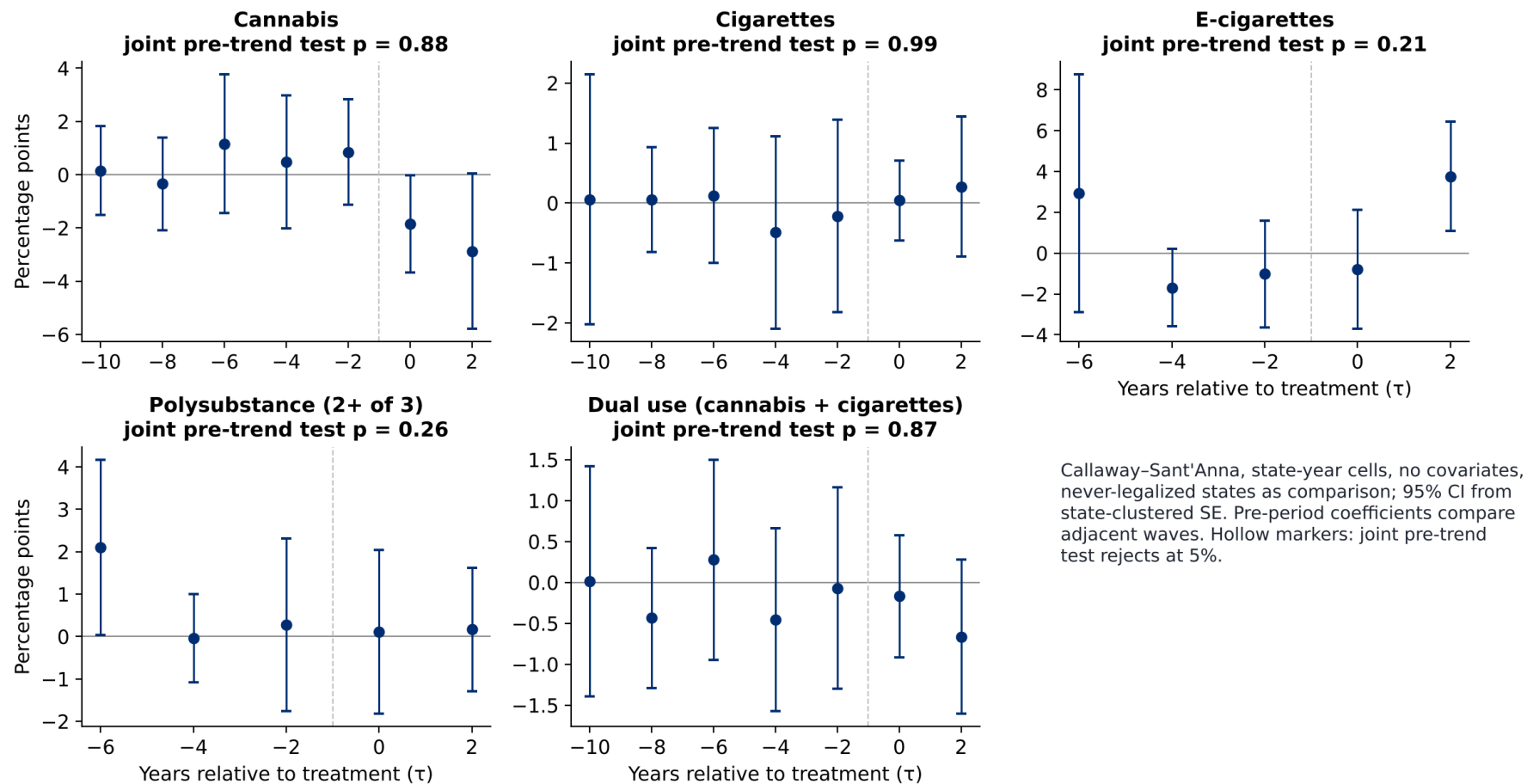
Outcome	RRCR 12 mo	RRCR 18 mo (main)	RRCR 24 mo	Legal baseline 12 mo	Legal baseline 18 mo	Legal baseline 24 mo
Cannabis	-1.96* (1.00) [8]	-2.07* (0.87) [10]	-1.80* (0.81) [13]	-1.75 (1.26) [4]	-2.09+ (1.17) [6]	-1.59 (0.97) [9]
Cigarettes	+0.15 (0.36) [8]	+0.10 (0.35) [9]	+0.08 (0.40) [12]	+0.02 (0.39) [4]	-0.32 (0.43) [5]	-0.16 (0.61) [8]
E-cigarettes	+1.82 (1.39) [7]	+0.20 (1.48) [9]	-0.26 (1.26) [12]	-2.27 (2.35) [4]	-3.53* (1.65) [6]	-2.56* (1.18) [9]
Polysubstance	+0.39 (0.86) [7]	+0.12 (0.81) [8]	+0.18 (0.63) [11]	-1.79+ (1.04) [4]	-1.80* (0.87) [5]	-0.51 (0.79) [8]
Dual use	-0.28 (0.40) [8]	-0.30 (0.35) [9]	-0.31 (0.29) [12]	-0.12 (0.26) [4]	-0.40 (0.31) [5]	-0.38 (0.35) [8]
Pre-trend p, cannabis	0.821	0.877	0.687	<0.001	0.012	0.043

Percentage points; SE clustered by state in parentheses; [] number of treated states; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$; grey: pre-trend test rejects at 5%.

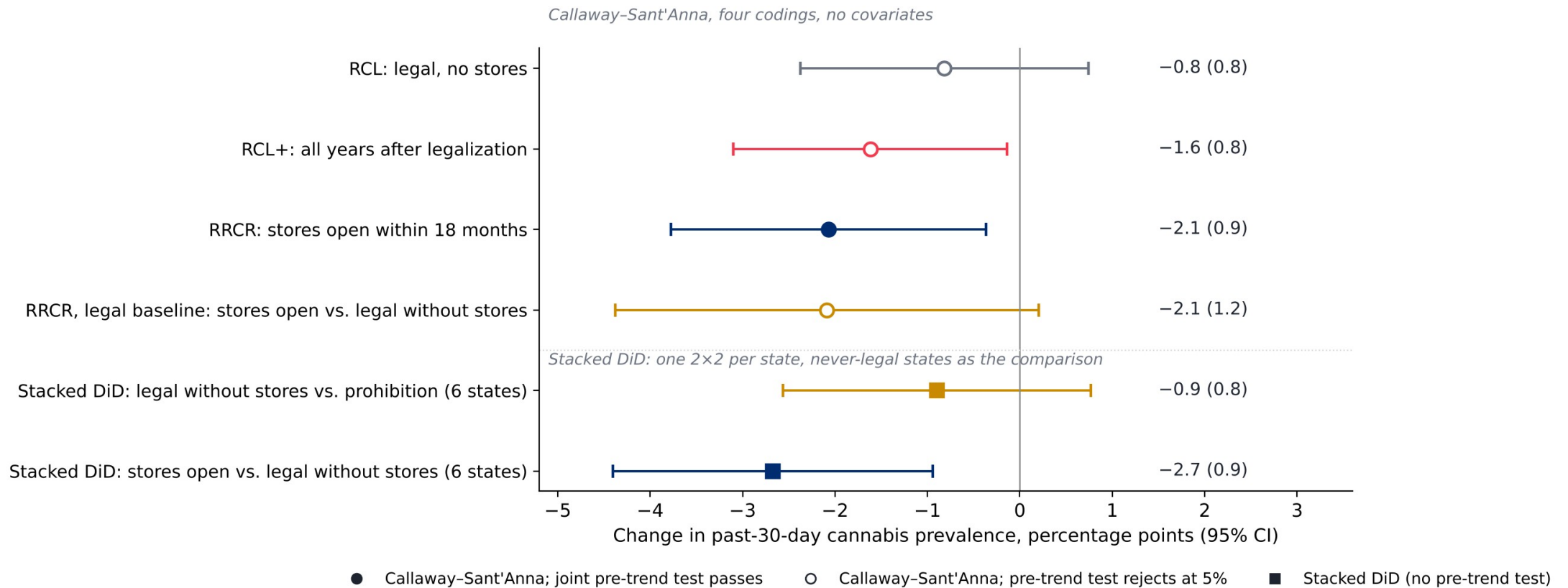
Event studies, cannabis: treatment dated at the stores (RRCR) vs. at the law (RCL+)



Event studies under RRCR, all five outcomes



Cannabis under the four codings and the stacked DiD



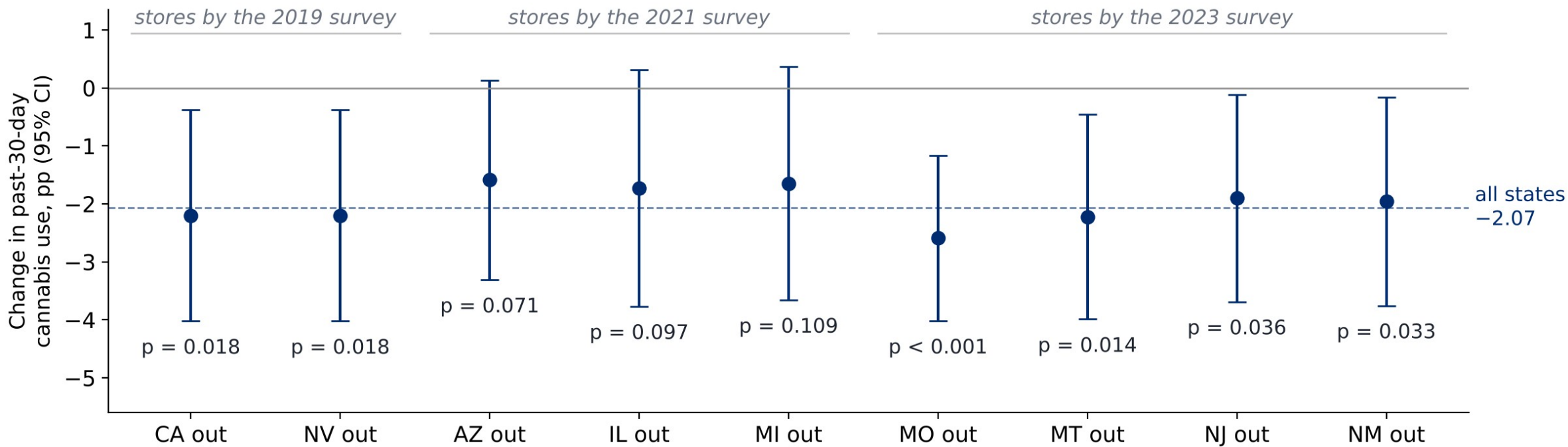
Stacked DiD: the legal step and the stores step, all five outcomes

Outcome	Legal without stores vs. prohibition (6 states)	Stores open vs. legal without stores (5–6 states)
Cannabis	−0.90 (0.85) [.357]	−2.67** (0.88) [.044]
Cigarettes	−0.07 (0.90) [.938]	−0.35 (0.21) [.123]
E-cigarettes	−0.68 (1.12) [.580]	−3.15* (1.40) [.044]
Polysubstance	−0.62 (0.60) [.368]	−1.22* (0.52) [.030]
Dual use	−0.41 (0.68) [.590]	−0.53** (0.19) [.026]

Percentage points; SE clustered by state in parentheses; [] wild cluster bootstrap p; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$.

Leave-one-out: each state dropped in turn

RRCR, Callaway-Sant'Anna, no covariates: each of the nine states that carry the estimate dropped in turn



Coding	All states	Estimate, one state dropped	p, one state dropped	Drops with p ≥ 0.05
RRCR	-2.07* (0.87)	-2.6 to -1.6	<0.001 to 0.109	3 of 46: AZ, IL, MI
RCL+	-1.62* (0.75)	-2.0 to -1.4	0.007 to 0.063	6 of 46: AZ, CA, CT, NM, NY, SD
RRCR, legal baseline	-2.09+ (1.17)	-2.5 to -1.7	0.032 to 0.201	38 of 42

Percentage points; SE clustered by state in parentheses; + p < 0.10, * p < 0.05, ** p < 0.01; bold: p < 0.05; grey: pre-trend test rejects at 5%.

By sex

Outcome	Boys: RCL+	Boys: RRCR	Girls: RCL+	Girls: RRCR
Cannabis	−1.95* (0.81)	−2.13* (0.87)	−1.35+ (0.79)	−1.97+ (1.10)
Cigarettes	+0.86 (0.62)	−0.59 (0.45)	+0.98 (0.66)	+0.78 (0.51)
E-cigarettes	+0.09 (1.19)	−0.92 (1.46)	+1.64 (1.59)	+1.41 (1.61)
Polysubstance	−0.14 (0.71)	−0.46 (0.67)	+1.22 (0.98)	+0.75 (1.17)
Dual use	−0.12 (0.36)	−0.52 (0.36)	−0.07 (0.41)	−0.09 (0.48)

Percentage points; SE clustered by state in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$; grey: pre-trend test rejects at 5%.

By age group and race/ethnicity: cannabis

Students	Pre-treatment rate (%)	RCL	RCL+	RRCR (main)	RRCR, legal baseline
Age 14–16	18.2	–1.00 (0.63)	–1.58* (0.67)	–2.57** (0.70)	–1.61 (1.21)
Age 17–18+	26.4	–0.55 (1.16)	–1.13 (1.08)	–0.44 (1.50)	–1.38 (1.21)
White	19.7	–0.71 (0.97)	–2.55* (1.03)	–3.38** (1.13)	–3.61* (1.62)
Black	24.7	–0.25 (1.47)	–0.43 (1.40)	–1.91 (1.48)	–2.76 (2.94)
Hispanic	23.8	+0.24 (1.18)	–0.23 (0.94)	–0.66 (1.08)	–1.20 (1.77)

Percentage points; SE clustered by state in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$; grey: pre-trend test rejects at 5%.

Intensity among those who still use: heavy use, all students

Among past-30-day users	Pre-treatment share (%)	RCL	RCL+	RRCR 18 mo (main)	RRCR 24 mo	Legal baseline 18 mo	Legal baseline 24 mo
Heavy cannabis (20+ days / times)	29.3	−1.02 (1.08)	−0.88 (0.97)	+1.19 (1.66)	+1.97 (1.43)	+2.31 (2.94)	+3.06+ (1.86)
Heavy cigarettes (20+ days / times)	26.1	−0.96 (1.85)	−0.46 (2.09)	+1.50 (2.74)	+0.04 (2.26)	+1.31 (4.99)	−1.35 (2.93)
Heavy vaping (20+ days / times)	25.3	+0.85 (1.44)	−1.24 (1.61)	−3.53 (2.58)	−2.74 (2.33)	−1.78 (3.61)	−1.45 (2.93)

Percentage points; SE clustered by state in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$; grey: pre-trend test rejects at 5%.

Intensity among those who still use, by subgroup

Among past-30-day users	Pre-treatment share (%)	RRCR 18 mo	pre-trend p	RRCR 24 mo	pre-trend p	RCL+ (dated at the law)	pre-trend p
Hispanic students: daily cannabis	18.6	+5.33** (1.81)	0.514	+5.25** (1.81)	0.552	+0.54 (1.66)	0.047
Hispanic students: heavy cannabis	28.8	+7.33** (2.32)	0.776	+6.45** (2.33)	0.709	+1.99 (1.86)	0.055
White students: heavy vaping	29.2	-8.31* (3.35)	0.298	-7.85** (2.94)	0.275	-1.35 (1.83)	0.679
Age 17–18+: heavy cannabis	33.6	+0.50 (2.40)	–	+1.08 (2.13)	–	-3.13* (1.27)	0.677

Percentage points; SE clustered by state in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$; bold: $p < 0.05$; grey: pre-trend test rejects at 5%.

Shown: significant at 5% under RRCR at 18 months and at 12 or 24, from more than four treated states, and the one RCL+ cell significant at 5%. Dashes: pre-trend test not run.

Results summary

- **Cannabis:** use falls about two points once stores open (-2.1^* RRCR; -2.7^{**} at the stores step), a tenth of the pre-treatment rate; no detectable change in the first legal year without stores (-0.9).
- **Tobacco:** no spillover under RRCR; weak evidence that e-cigarette, dual and polysubstance use fall when stores open in the six states that legalized first (-3.1^* , -0.5^{**} , -1.2^*).
- **Who:** the same for boys and girls; concentrated among 14–16-year-olds and White students; other groups smaller and imprecise.
- **How much:** nothing changes in daily or heavy cannabis use among those who still use, except among Hispanic users, where daily and heavy use rise; the decline is in occasional use.

Discussion

How this sits with the literature

	Why estimates may differ	What each is good for
Anderson et al. 2024	State YRBS 1993–2021. Legalization pools legal-no-stores and retail years ($\approx$ RCL+): -1.4 pp. "Sales allowed" turns on at the first sale, fast or slow: -2.2 to -2.6 pp	Our RCL+ -1.6 and RRCR -2.1 sit on their numbers
Coley et al. 2024	State YRBS 2011–2021. Count model; retail in a separate model with pre-retail years untreated; effects in times per month. First store: fewer users, more frequent use among users	On her years and codings: -0.8 after legalization, -2.0 after stores
Adults: Hyatt et al. 2025; Pawar et al. 2024	PATH adults 18+, Callaway–Sant'Anna: cannabis $+1.2$ pp before retail, $+3.7$ after. Meta-analysis: young adults OR 1.22 (post-2008 studies) vs. adolescents 1.09	Adult use rises most once stores open; teen use falls when they do
Tobacco outcomes (teens)	Coley 2021: any e-cigarette use up after legalization, before stores. Coley 2024: e-cigarette days -0.7 after retail. Weinberger 2022 (NSDUH 12–17): co-use and cigarette-only use down after legalization	No spillover under RRCR; weak evidence that vaping and co-use fall in the stores step (six legal-first states)

Possible mechanisms

Stores open: about -2 points

- Age-verified stores replace sellers who do not ask for ID (Anderson, Hansen, Rees & Sabia 2019; Coley et al. 2021)
- Stores check: all 175 audited in Colorado and Washington asked for ID (Buller et al. 2019)
- Enforcement moves use: Washington compliance checks cut youth past-month use 0.4–1.0 pp (Abouk, Maclean & Pacula 2025)

Limitations and next steps

Limitations

- **Few treated states, short post-period:** nine identifying states, one or two post-retail waves; inference borderline under conservative methods.
- **Mechanisms missing:** retail density, enforcement, prices, potency and local opt-outs unmeasured; the mechanism is a hypothesis.
- **Survey limitations**
 - Self-report from in-school youth
 - The vaping item does not separate nicotine from THC
 - No Oregon or Washington, Colorado in four waves

Next steps

- Add the 2025 YRBS wave: a second post-retail wave for the 2023 cohort and a first for CT, RI and MD.
- Slow rollout: estimate AK, MA, ME, VT and NY directly once 2025 adds their store waves.
- Measure what is vaped, nicotine or THC, before asking how cannabis policy moves 'e-cigarette' use.

Conclusions

- **1** The decline comes with the stores: past-30-day cannabis use falls about two points once stores open; no detectable change with legalization alone.
- **2** No spillover to cigarettes, e-cigarettes or co-use; weak evidence that vaping and co-use fall when stores open.
- **3** The decline is in occasional use, among 14–16-year-olds and White students.
- **4** Prompt, regulated retail did not raise adolescent use. Align cannabis and tobacco retail controls: age verification with enforcement, flavors, marketing, shared devices.

Thank you

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