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Cigarette smoking decline among US young adults from 2000 to 2019, in relation to state-level cigarette price and tobacco control expenditure

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ABSTRACT

Objective To investigate the association of state-level cigarette price and tobacco control expenditure with the large 2000–2019 decline in cigarette smoking among US 18–24 year-olds.

Methods Smoking behaviour was assessed in the 24 most populous US states using the 1992–2019 Tobacco Use Supplements to the Current Population Survey; association with price and expenditure was tested using adjusted logistic regression. States were ranked by inflation-adjusted average price and tobacco control expenditure and grouped into tertiles. State-specific time trends were estimated, with slope changes in 2001/2002 and 2010/2011.

Results Between 2000 and 2010, the odds of smoking among US young adults decreased by a third (adjusted OR, AOR 0.68, 95% CI 0.56 to 0.84). By 2019, these odds were one-quarter of their 2000 level (AOR 0.24, 95% CI 0.19 to 0.31). Among states in the lowest tertile of price/expenditure tobacco control activity, initially higher young adult smoking decreased by 13 percentage points from 2010 to 2018–2019, to a prevalence of 5.6% (95% CI 4.5% to 6.8%), equal to that in the highest tobacco-control tertile of states (6.5%, 95% CI 5.2% to 7.8%). Neither state tobacco control spending (AOR 1.0, 95% CI 0.999 to 1.002) nor cigarette price (AOR 0.96, 95% CI: 0.92 to 1.01) were associated with young adult smoking in statistical models. In 2019, seven states had prevalence over 3 SDs higher than the 24-state mean.

Conclusion National programmes may have filled a gap in state-level interventions, helping drive down the social acceptability of cigarette smoking among young adults across all states. Additional interventions are needed to assist high-prevalence states to further reduce smoking.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Tobacco control expenditures and increased cigarette prices are effective state- and national-level strategies which reduce cigarette smoking. US states varied considerably in implementation of these price/expenditure strategies. There was a major decline in cigarette smoking among US 18–24 year-olds, 2000–2019.

WHAT THIS STUDY ADDS

⇒ The 24 most populous states were ranked by price/expenditure activity level. Young adult smoking declined substantially across all states, and then decreased dramatically among the lowest price/expenditure states. 2019 prevalence was equal for the top and bottom tertile of states.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ There was a nationwide trend in the decline of US young adult smoking, including in states with both high and low tobacco control activity. National programs may have helped fill in gaps in state-level tobacco control activity.

INTRODUCTION

A major public health goal is to reduce the proportion of young people who become newly dependent cigarette smokers.[1] In the USA, cigarette smoking uptake has generally occurred between ages 12 and 24 years[2] and can be monitored using current smoking prevalence among young adults ages 18–24 years. Between 1998 and 2020, cigarette smoking declined by over 75% among both US adolescent[3] and young adult age groups.[4] E-cigarette use rose rapidly among adolescents between 2017 and 2019, but this was independent of the decrease in cigarette smoking.[4] Prior studies have shown that state-level interventions on cigarette price and tobacco control expenditures were associated with decreases in smoking among US adolescents ages 12–17 years.[5 6] However, the recent rapid decline in prevalence also suggests the possibility of a nationwide effect where cigarette smoking is no longer an acceptable or normative behaviour among US young people. Such a nationwide effect might overwhelm the expected effect from state-level tobacco control interventions.[7]

All US states had started taxing cigarettes by 1966 and these taxes have generally increased over time.[8] However, there are large differences across US states in the implementation of cigarette excise taxes, which increase price of cigarettes. There is a substantial health economics literature demonstrating that increases in cigarette taxes are associated with reductions in adult cigarette smoking prevalence.[9–11] Studies have differed on whether the effect on youth is greater than for adults.[12 13] US states also differ in their

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tobacco control expenditure. The first statewide comprehensive tobacco control programme in the USA started with a dedicated excise tax in California in 1988.[14] A major focus of the California campaign was de-normalising cigarette smoking among youth[15 16]; in the first decade, the proportion of 12–13 years who had even puffed on a cigarette declined by 70%.[17] Florida started an adolescent campaign in 1997, again focused on denormalising tobacco[18] and this also was associated with a substantial decline in adolescent smoking.[19 20]

In 1998, the Master Settlement Agreement (MSA) between the tobacco industry and state attorneys general related to lawsuits on smoking-related healthcare costs provided (a) about US$10 billion/year in unrestricted continuing payments to the states (which led to the tobacco industry increasing cigarette prices); (b) restrictions on advertising targeting minors and (c) funding for a foundation to run nationwide antismoking campaigns.[21] Particularly in the early years, some states expended a portion of the unrestricted monies from the MSA on tobacco control programmes. However, on the 25th anniversary of the MSA, it was noted that most states had chronically underfunded their tobacco prevention and cessation programmes.[22] A decade later, in 2009, the USA enacted into law the Family Smoking Prevention and Tobacco Control Act which increased federal cigarette taxes and gave the Food and Drug Administration (FDA) authority to regulate tobacco products.[23] One result of this was that the FDA launching a nationwide media campaign to reduce youth smoking.[24]

In this paper, we use the state and nationally representative Tobacco Use Supplements (TUS) to the Current Population Survey (CPS) to model the association of state-level cigarette price and tobacco control expenditures with the probability of smoking among young adults aged 18–24 years, 2000–2019, for the 24 most populous US states. We describe the heterogeneity across these states in both cigarette prices (1992–2019) and tobacco control expenditures (available 2000–2019), using publicly available data. We rank states on their average level of cigarette prices and tobacco control expenditure 2000–2019 and group them into tertiles of price/expenditure tobacco control activity. We estimate the change in prevalence by state and group for the periods 2000–2010 and 2010–2019.

METHODS

Data sources

The CPS is a rolling monthly survey of ~54 000 households that serves as the US labour force survey. Its design is state based and incorporates both national-level and state-level reliability requirements.[25] The TUS has been sponsored by the National Cancer Institute every 3–4 years since 1992. Each TUS consists of three independent monthly CPS samples at 4-month intervals, typically spanning 2 calendar years. Following enumeration, about one-third of TUS respondents are interviewed in person with the remainder surveyed by telephone. Response rates ranged from 62% (2007) to 75% (2019). We analysed the US population aged 18–24 years using the harmonised datafile of surveys from 1992/1993 to 2018/2019.[26] To ensure stable estimates, we restricted consideration to US states with a 2020 population >5 million. 24 states met this criterion, covering 82% of the US population. The combined 1992–2019 analytical sample was 90 313 respondents ages 18–24 and the 2000–2019 subsample was 54 408 respondents (online supplemental eTable 1). TUS-CPS documentation notes that the person-level survey weights are designed to account for missing data and provide representative state and national estimates.[26] Cigarette price data for each state in each year from 1991 to 2020 were obtained from the Tax Burden of Tobacco.[8] Annual state expenditures on tobacco control and recommended funding levels, adjusted for state population demographics, were taken from tabulated data provided by the Centers for Disease Control and Prevention (CDC) since 2000[22]

Measures

Cigarette smoking

Each TUS-CPS asked respondents if they had smoked 100 cigarettes in their lifetime and, if so, whether they now smoked every day, some days or not at all. Current established smokers are those who reported having smoked at least 100 cigarettes in their lifetime and currently smoked either every day or some days at the time of the survey.

Tobacco control expenditures

From the available tables,[22] we use the per cent of CDC recommended expenditure for each state and year.[27] For graphical presentation, we averaged the expenditure data over 4-year intervals (online supplemental eTable 3), In the statistical models, we used individual-year data.

State cigarette prices

Price data came from tobacco industry surveys and are reported as weighted state-specific averages for a pack of 20 cigarettes (including generic brands) as of 1 November each year.[8] Price was expressed in constant 2020 dollars for each year 1992–2019 using the Consumer Price Index[28] within each state. For graphical presentation, we computed the change in the average inflation-adjusted price across 4-year periods, however, statistical models used individual-year data (online supplemental eTable 4).

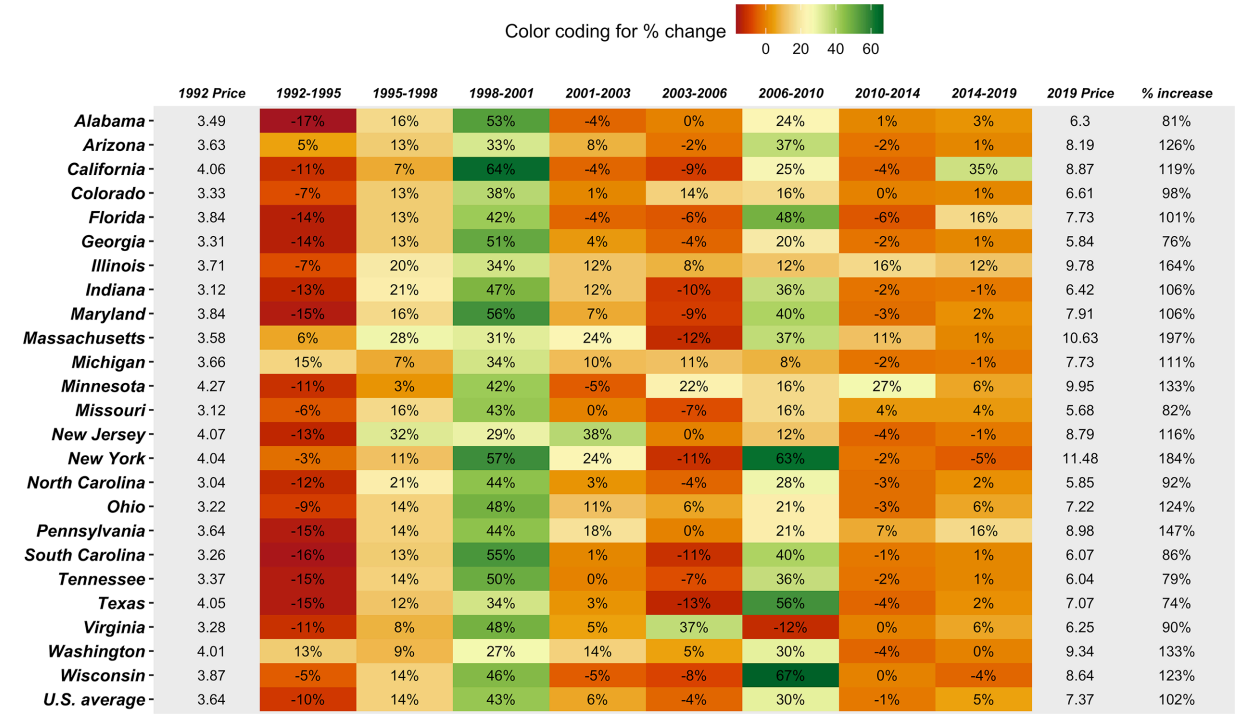
Sociodemographic covariates

There are known sociodemographic differences in smoking behaviour[29 30] and TUS-CPS uses standard questions to identify respondent sex, educational level and race ethnicity. Population distributions on these variables are in online supplemental eTable 1.

Data analysis

To visualise cigarette prices and tobacco control expenditures over time for the 24 US states, we present heatmaps[31] using a red-green spectrum, where red represents the least and green the most favourable tobacco control option. We ranked states on (a) the per cent increase in state price, adjusted to 2020 dollars and (b) the average proportion of CDC-recommended tobacco control spending over the study period and then summed these two ranks to provide an overall ranking of average state-level price/expenditure tobacco control activity. States were grouped into tertiles on this rank.

We investigated the association of individual smoking status with the state-level predictors (annual inflation-adjusted cigarette price and per cent of CDC recommended tobacco control expenditure) 2000–2019, which is the period of available expenditure data. All models were adjusted for individual-level confounders (sex, race/ethnicity and educational attainment). Price and expenditure were screened for statistical significance, and then indicators for state of residence and year were included in the model. State indicators were modelled as both fixed and random effects; with both linear and categorical time modelled as fixed effects. We selected the model with the lowest Akaike information criterion (AIC) (online supplemental eTable 5),



	1992 Price	1992-1995	1995-1998	1998-2001	2001-2003	2003-2006	2006-2010	2010-2014	2014-2019	2019 Price	% increase
Alabama	3.49	-17%	16%	53%	-4%	0%	24%	1%	3%	6.3	81%
Arizona	3.63	5%	13%	33%	8%	-2%	37%	-2%	1%	8.19	126%
California	4.06	-11%	7%	64%	-4%	-9%	25%	-4%	35%	8.87	119%
Colorado	3.33	-7%	13%	38%	1%	14%	16%	0%	1%	6.61	98%
Florida	3.84	-14%	13%	42%	-4%	-6%	48%	-6%	16%	7.73	101%
Georgia	3.31	-14%	13%	51%	4%	-4%	20%	-2%	1%	5.84	76%
Illinois	3.71	-7%	20%	34%	12%	8%	12%	16%	12%	9.78	164%
Indiana	3.12	-13%	21%	47%	12%	-10%	36%	-2%	-1%	6.42	106%
Maryland	3.84	-15%	16%	56%	7%	-9%	40%	-3%	2%	7.91	106%
Massachusetts	3.58	6%	28%	31%	24%	-12%	37%	11%	1%	10.63	197%
Michigan	3.66	15%	7%	34%	10%	11%	8%	-2%	-1%	7.73	111%
Minnesota	4.27	-11%	3%	42%	-5%	22%	16%	27%	6%	9.95	133%
Missouri	3.12	-6%	16%	43%	0%	-7%	16%	4%	4%	5.68	82%
New Jersey	4.07	-13%	32%	29%	38%	0%	12%	-4%	-1%	8.79	116%
New York	4.04	-3%	11%	57%	24%	-11%	63%	-2%	-5%	11.48	184%
North Carolina	3.04	-12%	21%	44%	3%	-4%	28%	-3%	2%	5.85	92%
Ohio	3.22	-9%	14%	48%	11%	6%	21%	-3%	6%	7.22	124%
Pennsylvania	3.64	-15%	14%	44%	18%	0%	21%	7%	16%	8.98	147%
South Carolina	3.26	-16%	13%	55%	1%	-11%	40%	-1%	1%	6.07	86%
Tennessee	3.37	-15%	14%	50%	0%	-7%	36%	-2%	1%	6.04	79%
Texas	4.05	-15%	12%	34%	3%	-13%	56%	-4%	2%	7.07	74%
Virginia	3.28	-11%	8%	48%	5%	37%	-12%	0%	6%	6.25	90%
Washington	4.01	13%	9%	27%	14%	5%	30%	-4%	0%	9.34	133%
Wisconsin	3.87	-5%	14%	46%	-5%	-8%	67%	0%	-4%	8.64	123%
U.S. average	3.64	-10%	14%	43%	6%	-4%	30%	-1%	5%	7.37	102%

Figure 1 Per cent changes in inflation-adjusted cigarette price for the 24 most populous US states, 1992–2019, with time periods matching the TUS-CPS survey periods. Heatmap using a red-green palette where dark red represents a price decrease and dark green a price increase. Data are presented in online supplemental eTable 4. Adapted from Orzechowski W, *et al*.[8] TUS-CPS, Tobacco Use Supplement to the Current Population Survey.

which assesses both lack of fit and model complexity.[32] As sensitivity analyses, we also present the next-best competitor model (online supplemental eTable 6). We also estimated post hoc modifications of the main model where we varied the inclusion of state, price, expenditure and time to address confounding (online supplemental eTable 7) and another model which allowed the effects of price and expenditure to differ pre and post 2010 (online supplemental eTable 8).

For each state and for the US as a whole, we display time trends in young adult smoking prevalence graphically from 1992 to 2019, using a piecewise linear model estimated by first-degree regression splines fitted to the aggregate prevalence for each state in each survey year.[33] We allowed two changes of slope: the first at 2001/2002 (previously identified start of the prevalence decline in 18–24 years[4]), and the second at 2010/2011 (midpoint of the ongoing decline). We grouped the states by tertiles of their average price/expenditure tobacco control activity and summarise the change in prevalence for each group of states.

Results are presented as proportions or ORs with 95% confidence limits and p values. All estimates are weighted by the survey weights, and p values and CIs used the published replicate weights.[26] We use non-overlapping CIs as a conservative measure of statistically significant differences. Analyses were carried out in R statistical software.

RESULTS

State-level average cigarette price, 1992–2019

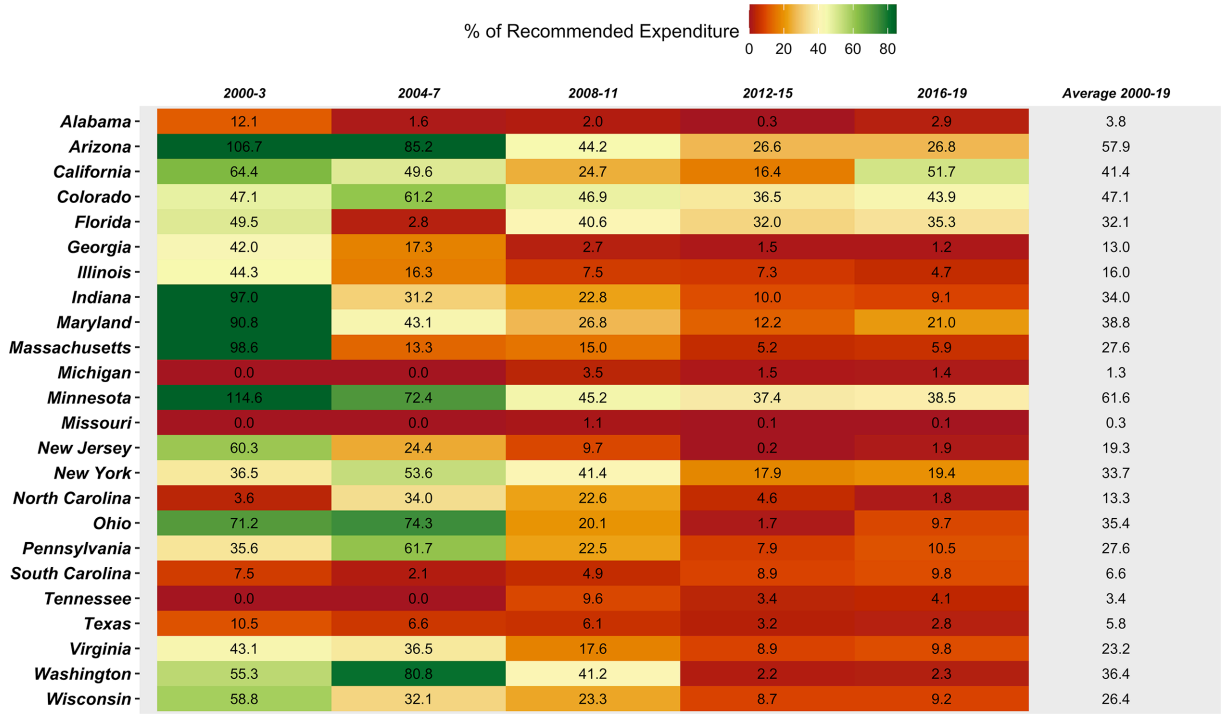
In 1992, across the 24 most populous US states, there was a 40% difference between the highest and lowest average cigarette price (range in 2020 dollars: US$3.04–US$4.27) (figure 1, column 1, online supplemental eTable 4). Changes in price over time tended to be synchronised across states, as indicated by the colours of the heatmap. Considering the 24 states, from 1998 to 2001, 17 states had increases of at least 40% (figure 1, column 4), with a 43.3% increase in average prices; from 2006 to 2010 prices increased by 30.3% on average (figure 1, column 7). In other time periods, prices were relatively stable, with a few outliers. By 2019, prices varied across states from a low of US$5.68/pack in Missouri to a high of US$11.48/pack in New York. Over the study period, the largest overall price increases occurred in Massachusetts (+197%) and New York (+184%); there were six states with less than half that level of increase: Virginia (+90%), South Carolina (+86%), Missouri (+82%), Alabama (+81%), Tennessee (+79%), Georgia (+76%) and Texas (+74%).

State expenditure on tobacco control programmes, 2000–2019

In the early years following the MSA, from 2000 to 2003, the 24 most populous states spent an average of 44.4% of CDC recommended tobacco control expenditures (figure 2 column 1 and online supplemental eTable 3). There was heterogeneity across states: five states spent more than 90% of recommended levels, and five states spent less than 10%. In 2004–2007, average expenditure was 34.8% of recommended levels, but then after 2012 expenditure was about half of that level. Across the period 2000–2019, the top four states averaged more than 40% of CDC recommended expenditures: Minnesota (62%), Arizona (58%), Colorado (47%) and California (41%). The lowest ranked states had expenditures which averaged 7% or less of CDC recommended expenditure across the period (South Carolina (7%), Texas (6%), Alabama (4%), Tennessee (3%), Michigan (1%), Missouri (<1%)).

Association of 18–24 years cigarette smoking with state-level price and expenditure, 2000–2019

We used weighted logistic regression to model the probability of smoking among US 18–24 years who were residents of one



	2000-3	2004-7	2008-11	2012-15	2016-19	Average 2000-19
Alabama	12.1	1.6	2.0	0.3	2.9	3.8
Arizona	106.7	85.2	44.2	26.6	26.8	57.9
California	64.4	49.6	24.7	16.4	51.7	41.4
Colorado	47.1	61.2	46.9	36.5	43.9	47.1
Florida	49.5	2.8	40.6	32.0	35.3	32.1
Georgia	42.0	17.3	2.7	1.5	1.2	13.0
Illinois	44.3	16.3	7.5	7.3	4.7	16.0
Indiana	97.0	31.2	22.8	10.0	9.1	34.0
Maryland	90.8	43.1	26.8	12.2	21.0	38.8
Massachusetts	98.6	13.3	15.0	5.2	5.9	27.6
Michigan	0.0	0.0	3.5	1.5	1.4	1.3
Minnesota	114.6	72.4	45.2	37.4	38.5	61.6
Missouri	0.0	0.0	1.1	0.1	0.1	0.3
New Jersey	60.3	24.4	9.7	0.2	1.9	19.3
New York	36.5	53.6	41.4	17.9	19.4	33.7
North Carolina	3.6	34.0	22.6	4.6	1.8	13.3
Ohio	71.2	74.3	20.1	1.7	9.7	35.4
Pennsylvania	35.6	61.7	22.5	7.9	10.5	27.6
South Carolina	7.5	2.1	4.9	8.9	9.8	6.6
Tennessee	0.0	0.0	9.6	3.4	4.1	3.4
Texas	10.5	6.6	6.1	3.2	2.8	5.8
Virginia	43.1	36.5	17.6	8.9	9.8	23.2
Washington	55.3	80.8	41.2	2.2	2.3	36.4
Wisconsin	58.8	32.1	23.3	8.7	9.2	26.4

Figure 2 Per cent of CDC-recommended state expenditures on tobacco prevention programmes over consecutive 4-year periods in the 24 most populous US states. Heatmap using a red-green palette where dark red is zero expenditure and dark green 80% of recommended expenditure level. Data are presented in online supplemental eTable 3 Adapted from Campaign for Tobacco Free Kids[22] Recommended levels from CDC recommends best practices for tobacco control expenditure. CDC, Centers for Disease Control and Prevention.

of the 24 most populous states, adjusting for gender, education and race/ethnicity. Predictors included state, survey year (2000 to 2019), state-level tobacco control expenditure and average state cigarette price; the best-fitting model was chosen by AIC, considering either fixed (selected) or random effects for state and linear or categorical (selected) time and interaction terms (excluded) (online supplemental eTable 5). In the final model (table 1), neither state-level tobacco control expenditure (adjusted OR AOR 1.00, 95% CI 0.999 to 1.002, p=0.64) nor cigarette price (AOR 0.96, 95% CI 0.92 to 1.01, p=0.12) added significant information to smoking prevalence over and above the main effects of the time and state indicators. Time had a strong effect: with each successive year, the odds of cigarette smoking decreased from the reference year (2000, 18–24 years smoking prevalence: 25.8%, 95% CI 24.5% to 27.0%). By 2010, the odds of smoking were reduced by a third from 2000 (AOR 0.68, 95% CI 0.56 to 0.84). By 2019, these odds were one-quarter of the 2000 level (AOR 0.24, 95% CI 0.19 to 0.31). With Indiana chosen as the reference state, eight states had an average prevalence significantly lower than this state. Sex, race ethnicity and education had significant effects in the expected direction. We also present the best model (chosen by AIC) which incorporated the state indicators as a random effect (online supplemental eTable 6). Effect size estimates were very similar, although price was nominally statistically significant in this model. However, it did not use survey weights or replicate weights due to a limitation of the software so should be interpreted with caution.

We used several sensitivity analyses to explore the confounding of the state-level price and expenditure data with the state and time indicators (online supplemental eTable 7). In many models, the effect of price was significant and in the expected direction. However, the effect of price was sensitive to the inclusion of both time and state, indicating confounding with these factors. State tobacco control expenditure was associated with an increased likelihood of young adult smoking in most but not all models, again indicating confounding. We also added a post hoc term to the final model (table 1) which allowed the effects of price and expenditure to differ before and after the year 2010 (online supplemental eTable 8). While neither variable was significant, results are consistent with a larger effect of price in the earlier period (p=0.07), with no evidence of an effect after 2010.

Smoking prevalence among 18–24 years in 24 US states, 1992–2019, ranked by average price/expenditure levels

For each state, we estimated a linear trend over time in young adult smoking prevalence, allowing for a change in slope at 2001/2002 and at 2010/2011 (figure 3). States are grouped into tertiles of average price plus expenditure levels (panel A: highest; panel B: middle, panel C: lowest price/expenditure tobacco control activity group). The heavy line represents prevalence for the state; the dotted line is the average prevalence across all 50 states; and the shaded boundaries show the highest and lowest state prevalence from among the 24 US states studied. Estimated prevalence at selected time points is presented in table 2; complete data are in online supplemental eTable 2.

In 1992/1993, US young adult smoking prevalence was 25.3% (95% CI 24.7% to 26.0%), and only California, New York and Maryland had a significantly lower prevalence (online supplemental eTable 2). Between 2001/2002 and 2010/2011, young adult smoking declined significantly in six of the eight states in the highest price/expenditure tobacco control activity group and average prevalence in this group declined by 8.9 percentage points, from 23.0% (95% CI 21.6% to 24.5%) to 14.1% (95% CI 12.8% to 15.4%) (table 2). In the middle price/expenditure

Table 1 Logistic regression model* with outcome current smoking, for respondents aged 18–24 years in the 24 most populous US states:2000–2018/2019: data from TUS-CPS

Independent variables		Adjusted OR (95% CI)	P value
(Intercept)		0.507 (0.362 to 0.709)	<0.0001
Time (survey year)	2000	Reference	
	2001	0.991 (0.815 to 1.206)	0.9295
	2002	0.937 (0.779 to 1.128)	0.4897
	2003	0.852 (0.709 to 1.025)	0.0884
	2006	0.812 (0.674 to 0.980)	0.0297
	2007	0.725 (0.595 to 0.884)	0.0016
	2010	0.683 (0.556 to 0.839)	0.0003
	2011	0.613 (0.489 to 0.769)	<0.0001
	2014	0.491 (0.383 to 0.630)	<0.0001
	2015	0.481 (0.385 to 0.601)	<0.0001
	2018	0.275 (0.204 to 0.371)	<0.0001
	2019	0.240 (0.185 to 0.311)	<0.0001
Sex	Male	Reference	
	Female	0.758 (0.720 to 0.797)	<0.0001
Education	Any college	Reference	
	No college	2.114 (1.999 to 2.235)	<0.0001
Race ethnicity	NHW	Reference	
	NH Black	0.468 (0.426 to 0.515)	<0.0001
	Other/multiple races	1.235 (1.031 to 1.480)	0.0224
	API	0.505 (0.429 to 0.594)	<0.0001
	Hispanic/Latino	0.353 (0.322 to 0.388)	<0.0001
Policy: expenditure	State Tobacco Control Expenditure	1.000 (0.999 to 1.002)	0.6442
Policy: price	State Cigarette Price	0.964 (0.919 to 1.010)	0.1241
State indicator (fixed effect)	Indiana	Reference	
	California	0.580 (0.476 to 0.705)	<0.0001
	Florida	0.642 (0.527 to 0.783)	<0.0001
	New Jersey	0.672 (0.508 to 0.889)	0.0056
	Massachusetts	0.707 (0.532 to 0.938)	0.0167
	Texas	0.788 (0.644 to 0.964)	0.0207
	Georgia	0.757 (0.590 to 0.972)	0.0294
	Maryland	0.747 (0.568 to 0.981)	0.036
	Pennsylvania	0.817 (0.669 to 0.998)	0.048
	Arizona	0.814 (0.642 to 1.031)	0.0876
	Virginia	0.824 (0.649 to 1.046)	0.1117
	New York	0.814 (0.614 to 1.078)	0.1505
	Illinois	0.850 (0.669 to 1.080)	0.1827
	Minnesota	0.872 (0.698 to 1.090)	0.2276
	South Carolina	0.863 (0.668 to 1.114)	0.2562
	Colorado	0.909 (0.725 to 1.141)	0.4109
	Tennessee	0.919 (0.736 to 1.149)	0.4574
	Michigan	0.927 (0.736 to 1.167)	0.5170
	Washington	0.921 (0.711 to 1.193)	0.5301
	Ohio	0.939 (0.767 to 1.150)	0.5403
	Missouri	0.960 (0.754 to 1.221)	0.7357
	Wisconsin	1.038(0.822 to 1.310)	0.7556
	Alabama	0.988 (0.743 to 1.313)	0.9312
	North Carolina	0.995 (0.797 to 1.242)	0.9628

*The model presented is the one with the lowest AIC, thus providing the best balance between the goodness of fit of the model with its complexity (see online supplemental eTable 5). State tobacco expenditure is the per cent of CDC recommended expenditure per capita for each year.[25 26] State Cigarette Price is the estimated average cigarette price reported by Tax Burden on Tobacco[24] adjusted to 2020 dollars by Consumer Price Index. States are ordered by difference from the reference state (Indiana) as assessed by the p value.
AIC, Akaike information criterion; CDC, Centers for Disease Control and Prevention; TUS-CPS, Tobacco Use Supplement to the Current Population Survey.

group, only three states had significant declines (Colorado, Illinois and Wisconsin) and average prevalence for the middle group declined by 9.1 percentage points, from 26.8% (95% CI 25.1% to 28.5%) to 17.7% (95% CI 16.0% to 19.3%). Among the eight states in the lowest price/expenditure group, only two states (Virginia and Michigan) had significant declines in young adult smoking and the average prevalence for states in this group declined by 7.6 percentage points, from 26.2% (95% CI 24.3% to 28.1%) to 18.6% (95% CI 16.9% to 20.3%)

From 2010/2011 to 2018/2019, for the group of eight highest ranked states on price/expenditure activity, average young adult smoking prevalence declined by 7.6 percentage points, from 14.1% to 6.5% (95% CI 5.2% to 7.8%). The only state in this group without a significant decline was California, which was low on cigarette price and TC expenditure for the majority of this time. For the middle group, five of the eight states experienced significant young adult smoking declines; average prevalence in this group of states declined by 9.4 percentage points, from 17.7% to 8.3% (95% CI 6.6% to 9.9%). For the lowest group, six of the eight states had significant declines, with four having very large declines (Missouri 83%; Virginia 79%; Texas 75% and South Carolina 74%); average state young adult smoking prevalence for the group declined by 13 percentage points, from 18.6% to 5.6% (95% CI 4.5% to 6.8%).

Thus, while the highest price/expenditure groups experienced the largest decline in young adult smoking in the earlier time period (2001–2011), in the later period (2011–2019) this was reversed, and the lowest group had the largest decline. By the end of the study period, the prevalence of young adult smoking was similar for the highest (6.5%, 95% CI 5.2% to 7.8%) and lowest (5.6%, 95% CI 4.5% to 6.8%) price/expenditure groups of states. The 24-state mean prevalence was 6.7% (95% CI 5.9% to 7.6%) and there were seven states with a smoking prevalence more than 3 SDs above this mean (Ohio, Illinois, Indiana, Maryland, North Carolina Tennessee and Alabama); these came from each of the three tertiles.

DISCUSSION

Between 2000 and 2019, there was substantial heterogeneity across the 24 most populous US states in the level of both cigarette prices and expenditures on tobacco control programmes. However, all of these states experienced a major decline in young adult smoking prevalence over the period. In adjusted logistic regression models, after including the strong overall time effect and differing state-level intercepts, neither state-level price nor tobacco control expenditure was a significant predictor of young adult cigarette smoking. When we grouped the states into price/expenditure tobacco control activity tertiles, the highest activity tertile experienced the largest drop in young adult smoking prevalence between 2001/2002 and 2010/2011, confirming what has previously been reported.[34] However, from 2010/2011 to 2018/2019, the lowest activity group experienced the largest drop in young adult smoking, and, as a group, caught up to the low smoking prevalence of the highest price/expenditure group of states. There were seven states that lagged notably in their cigarette smoking decline compared with states in their tertile of price/expenditure rankings. Additional study is needed to identify influences that might be counteracting the strong national downward decline in cigarette smoking in this age group.

It has been proposed that the rise in e-cigarette vaping,[35] which was particularly marked in adolescents after 2017,[36] was a major driver of the decline in 18–24 years cigarette smoking between 2010 and 2020. However, in a recent paper, we provided evidence that the decline in young adult smoking was largely independent of the rise in e-cigarettes.[4] Importantly, most of the decline in young adult prevalence occurred prior to the surge

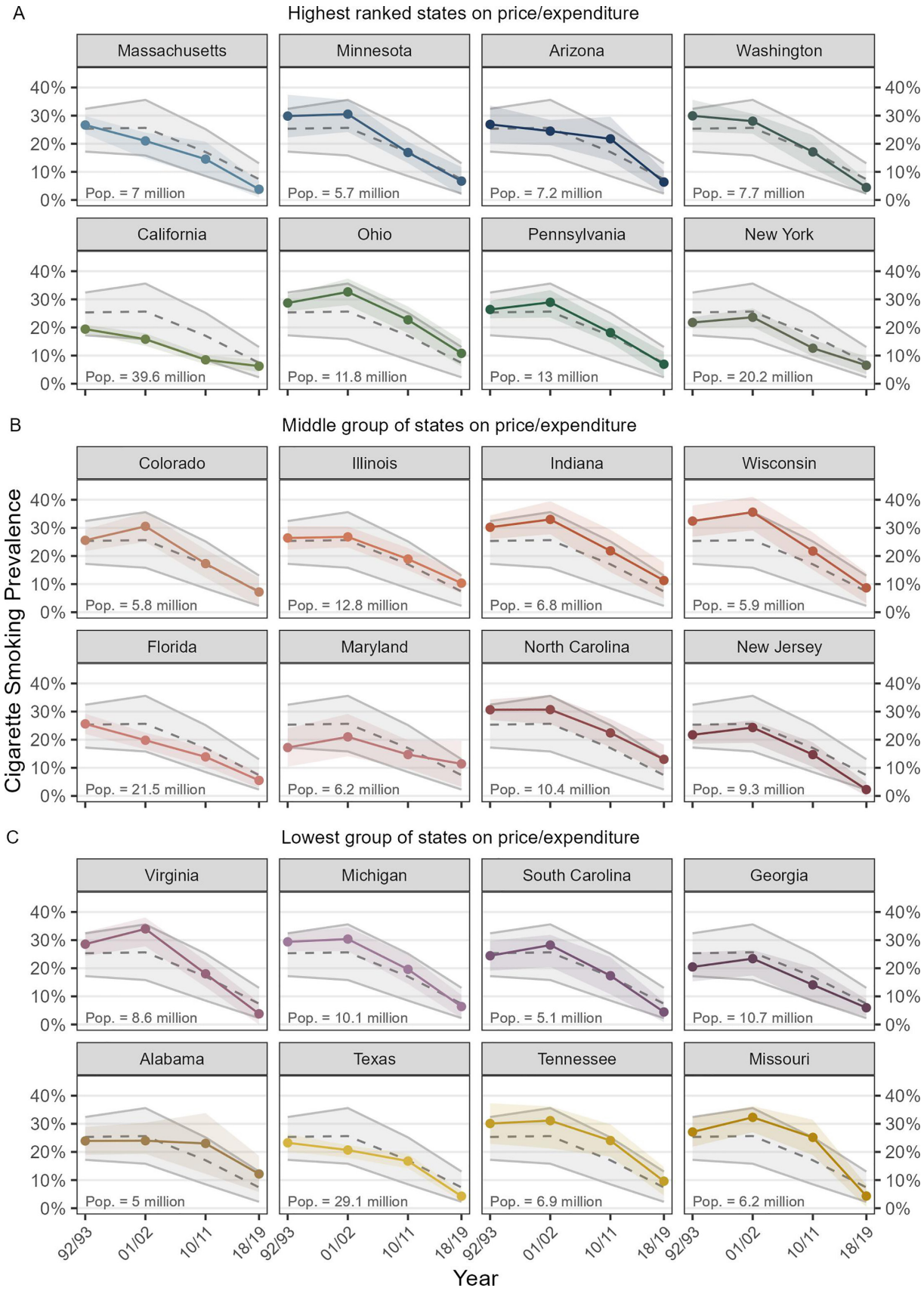


Figure 3 Time trends in state-specific cigarette smoking prevalence among 18–24 years, for the 24 most populous US states ranked by aggressiveness of tobacco control policies. Grey bands represent the minimum and maximum prevalence rate observed across the 24 most populous states. The dashed grey line is the US national cigarette smoking prevalence among 18–24 years. Source: TUS-CPS 1992/1993–2018/2019. Data are presented in online supplemental eTable 2. TUS-CPS, Tobacco Use Supplement to the Current Population Survey.

Table 2 Prevalence of 18–24 years cigarette smoking for 24 most populous US states grouped by state aggressiveness on tobacco control spending and cigarette price

	State	2001/2002		2010/2011		2018/2019	
Tob cont rank		Prev*	95% CI	Prev*	95% CI	Prev	95% CI
Highest ranked states on price/expenditure							
1	Massachusetts	21.0%	(14.7 to 27.3)	14.5%	(8.3 to 20.7)	**3.8%**	(0.9 to 6.8)
2	Minnesota	30.5%	(24.2 to 36.8)	**16.9%**	(13.1 to 20.6)	**6.7%**	(1.7 to 11.7)
3	Arizona	24.5%	(19.5 to 29.5)	21.8%	(14.0 to 29.5)	**6.4%**	(2.4 to 10.3)
4	Washington	28.0%	(23.5 to 32.5)	**17.1%**	(11.1 to 23.0)	**4.5%**	(1.8 to 7.1)
5	California	15.8%	(13.5 to 18.2)	**8.5%**	(6.9 to 10.1)	6.2%	(4.1 to 8.4)
b	Ohio	32.6%	(27.9 to 37.4)	**22.7%**	(18.0 to 27.4)	**10.8%**	(6.1 to 15.5)
7	Pennsylvania	28.9%	(23.5 to 34.4)	**18.2%**	(14.5 to 21.8)	**6.9%**	(2.6 to 11.3)
8	New York	23.6%	(20.1 to 27.1)	**12.6%**	(9.7 to 15.5)	**6.5%**	(3.4 to 9.7)
	Subgroup Average	23.0%	(21.6 to 24.5)	**14.1%**	(12.8 to 15.4)	**6.5%**	(5.2 to 7.8)
Middle group of states on price/expenditure							
9	Colorado	30.5%	(25.0 to 36.1)	**17.3%**	(12.3 to 22.3)	**7.2%**	(2.2 to 12.2)
10	Illinois	26.8%	(23.1 to 30.5)	**18.9%**	(15.0 to 22.8)	**10.3%**	(6.7 to 14.0)
11	Indiana	33.0%	(27.8 to 38.2)	21.8%	(14.3 to 29.3)	11.3%	(4.8 to 17.7)
12	Wisconsin	35.6%	(29.1 to 42.0)	**21.7%**	(15.1 to 28.3)	**8.7%**	(3.3 to 14.1)
13	Florida	19.8%	(16.6 to 23.0)	13.9%	(10.5 to 17.3)	**5.5%**	(2.8 to 8.2)
14	Maryland	21.0%	(14.1 to 27.9)	14.7%	(9.6 to 19.8)	11.4%	(3.3 to 19.5)
15	North Carolina	30.7%	(25.5 to 35.9)	22.4%	(17.5 to 27.4)	13.0%	(7.9 to 18.1)
16	New Jersey	24.3%	(18.9 to 29.8)	14.7%	(10.3 to 19.0)	**2.3%**	(0 to 4.8)
	Subgroup Average	26.8%	(25.1 to 28.5)	**17.7%**	(16.0 to 19.3)	**8.3%**	(6.6 to 9.9)
Lowest group of states on price/expenditure							
17	Virginia	34.0%	(27.8 to 40.2)	**18.0%**	(13.3 to 22.7)	**3.8%**	(0 to 7.8)
18	Michigan	30.4%	(26.1 to 34.7)	**19.6%**	(14.4 to 24.8)	**6.4%**	(2.3 to 10.5)
19	South Carolina	28.2%	(20.5% to 36.0)	17.4%	(10.8 to 23.9)	**4.4%**	(0.8 to 8.1)
20	Georgia	23.4%	(17.4 to 29.4)	14.1%	(7.9 to 20.3)	6.0%	(2.9 to 9.0)
21	Alabama	24.0%	(19.3 to 28.7)	23.0%	(12.3 to 33.8)	12.2%	(5.8 to 18.5)
22	Texas	20.7%	(18.0 to 23.4)	16.8%	(14.2 to 19.3)	**4.3%**	(2.6 to 5.9)
23	Tennessee	31.1%	(21.3 to 40.9)	24.1%	(18.3 to 29.8)	**9.6%**	(4.5 to 14.7)
24	Missouri	32.3%	(27.0 to 37.6)	25.2%	(18.9 to 31.4)	**4.3%**	(0.4 to 8.3)
	Subgroup average	26.2%	(24.3 to 28.1)	**18.6%**	(16.9 to 20.3)	**5.6%**	(4.5 to 6.8)
	24 state mean	25.0%	(24.1 to 26.0)	**16.4%**	(15.6 to 17.2)	**6.7%**	(5.9 to 7.6)

Bold numbers indicate signifcant difference from the previous survey estimate (p<0.05).
*Prev=cigarette smoking prevalence.

in e-cigarette vaping, which occurred between 2014 and 2019. In only 4 of the 24 states was the rise in young adult e-cigarette vaping large enough to have replaced the observed decline in cigarette smoking. Across states, during this period, the correlation over time between vaping and smoking prevalence was a low 0.11. Thus, at best, e-cigarettes were a minor influence on the decline in smoking among US young adults.

In many of the logistic regression models of young adult smoking that we investigated the effect of tobacco control expenditure went in an unexpected direction, in which increased expenditure predicted increased probability of smoking. This indicates confounding of expenditure levels with other influences on young adult smoking prevalence, including cigarette price, other state-level influences and national time trends. There was also a striking level of change between 2010/2011 and 2018/2019 among the states in the lowest group as ranked on price/expenditure tobacco control activity. A likely explanation for this is the effectiveness of national campaigns that have targeted denormalisation of smoking among US youth, including the 'Truth Initiative', which conducted US-wide campaigns across the entire study period,[37–40] and the FDA's Real Costs campaign, which started in 2014.[23 41 42] Other tobacco control initiatives with national scope include the successful 'Tobacco 21' advocacy campaign for federal legislation to raise the legal age for purchase of tobacco products to 21 years[43]; the dissemination of smoke-free school campuses[44] and state enforcement of the MSA restrictions on national cigarette advertising aimed at youth.[45] There was also widespread dissemination of the harms of secondhand smoke and an accompanying voluntary introduction of smoke-free homes[46] during the study period, which can reduce young adult smoking prevalence.[47] Indeed, in 2018/2019, the proportion reporting a smoke-free home in Missouri (the state in our study with the lowest price/expenditure ranking) was the same as the US national average (78.6% vs 79.7%, data are not shown). This suggests that there may have been a major national trend away from the acceptability of smoking.

The lack of effect of state-level price in the final regression model may be because price changes were somewhat similar across states during the study period, leading to confounding of price with time. In addition, price changes were relatively modest: outside of periods associated with the implementation of the MSA (21) and the federal tax increase associated with the 2009 Tobacco Control Act (23), few states had price increases above 15% for the study period. This is far less than the yearly

increases implemented in Australia that were associated with a prevalence decline.[48] It may suggest that higher prices may be needed to see significant changes in youth smoking rates.

Strengths and limitations

Strengths of the study include the use of large repeated cross-sectional surveys incorporating standard cigarette smoking questions to provide both state-specific and nationally representative prevalence estimates. Limitations include our use of cross-sectional rather than longitudinal data and that we did not include measures of the social acceptability of smoking among the study population. It is important to note that the inability of our analyses to quantify the effects of state-level prices and tobacco expenditure appears to be a limitation of these data, in the context of a national public health success in reducing youth cigarette smoking. We explicitly identified confounding of state expenditure levels with cigarette price, other state-level influences, and national time trends in these data; thus, our models are not evidence of lack of effect, but of the limitations of this approach. Our results suggest that the changing acceptability of cigarette smoking should be further explored as a possible explanation for the rapid decline in US youth smoking. Our results suggest that the changing acceptability of cigarette smoking should be further explored as a possible explanation for the rapid decline in US youth smoking.

CONCLUSIONS

The large decline in US 18–24 years cigarette smoking prevalence between 2001/2002 and 2018/2019 occurred broadly, across states with both relatively high and relatively low cigarette prices and tobacco control expenditures. This suggests a public health benefit from the national tobacco control programmes, helping drive down the social acceptability of cigarette smoking across all states and thus filling in gaps in state-level activity. Additional increases in cigarette price and tobacco control spending at the state level are needed to further drive down cigarette smoking among young adults. Additional research is needed to identify influences that are impeding this decline in several states, and whether the social acceptability of smoking is a key variable associated with the decrease in young adult smoking.

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