

Research Article

Forty Years of Faster Decline in Cigarette Smoking in California Explains Current Lower Lung Cancer Rates

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Abstract

Background: Declining lung cancer rates in California have been attributed to the California Tobacco Control Program, but may reflect earlier declines in smoking.

Methods: Using state-taxed sales and three survey series, we assessed trends in smoking behavior for California and the rest of the nation from 1960 to 2008 and compared these with lung cancer mortality rates. We tested the validity of recent trends in state-taxed sales by projecting results from a model of the 1960 to 2002 data.

Results: From 1960 to 2002, the state-taxed sales and survey data are consistent. Californians initially smoked more than the rest of the nation, but cigarette consumption declined earlier, dropping lower in 1971 with an ever widening gap over time. Lung cancer mortality follows a similar pattern, after a lag of 16 years. Introduction of the California Tobacco Control Program doubled the rate of decline in cigarette consumption. From 2002 to 2008, differences in enforcement and tax evasion may compromise the validity of the taxed sales data. In 2010, smoking prevalence is estimated to be 9.3% in California and 17.8% in the rest of the nation. However, in 2008, for the first time, both cigarette price and tobacco control expenditures were lower in California than the rest of the nation, suggesting that the gap in smoking behavior will start to narrow.

Conclusion: An effective Tobacco Control Program means that California will have faster declines in lung cancer than the rest of the nation for the next 2 decades, but possibly not beyond.

Impact: Tobacco control interventions need further dissemination. *Cancer Epidemiol Biomarkers Prev*; 19(11); 2801–10. ©2010 AACR.

Introduction

California has been widely recognized as an early adopter of tobacco control interventions, and especially recognized for the effectiveness of its first-in-the-nation comprehensive Tobacco Control Program, which began

in 1989. The program was associated with declines in cigarette sales and in smoking prevalence (1, 2) brought about by declines in initiation (3, 4) and consumption (5, 6) as well as increased cessation, although this was restricted to young adults (1, 2). Lung cancer mortality rates in California declined in the years following the initiation of the Tobacco Control Program, leading to conjecture that the program was responsible for these state-specific declines (7-10). Such a hypothesis is in line with the individual smoker lung cancer risk, which can decrease by 20% within 5 years of cessation (11). However, a population-level analysis, which correlated 100 years of annual lung cancer rates with lagged taxed cigarette sales data, reported zero correlation between these variables at a lag of 5 years, increasing over 0.75 for lags of 16 to 28 years, and a maximum correlation of 0.83 at a lag of 21 years (12). This suggests that the majority of California's drop in lung cancer rates may be due to factors that predate the California Tobacco Control Program.

After the first Surgeon-General's report in 1964 (13) concluded that smoking caused cancer, a series of national tobacco control interventions ensued. These included health warnings on tobacco packs (1966), mass media antismoking public service announcements (1967), a general legislative ban on broadcast cigarette advertising (1971), and the creation of nonsmoking sections on aircrafts (1973;

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ref. 14). At the state level, California had the most aggressive tobacco control response with a major increase in cigarette excise taxes in 1968 (15). Although Minnesota was the first to have statewide clean indoor air legislation (1975), California pioneered local government ordinances for smoke-free workplace policies, starting in Berkeley in 1976 (16). In 1988, California established the first statewide comprehensive tobacco control program (17, 18). In 1994, 8 years before any other state, the California legislature passed the first statewide smoke-free workplace law (19).

By the year 2000, there was a marked difference across the nation in state cigarette taxes and concern was expressed that there might be illegal smuggling across state lines (20, 21). To counter this, in 2003, California began licensing tobacco retailers throughout the state and increased the number of inspectors, and in 2005 implemented an electronically enhanced cigarette tax stamp to facilitate monitoring and reduce tax evasion. These activities have reportedly increased cigarette tax revenues significantly (22), whereas tax evasion seems to be a growing problem in the rest of the nation (23, 24).

In this study, we compare changes in cigarette smoking between California and the rest of the nation starting in 1960 (i.e., before the national public health antismoking campaign) through 2008. We address each of the following hypotheses:

1. Comparing California with the rest of the nation, trends in relative per capita cigarette consumption will be similar whether estimated from the taxed sales or survey data, at least through 2002.
2. The California Tobacco Control Program will be associated with a major change in the decline in smoking behavior, particularly in estimates of per capita cigarette consumption.
3. From 1970 through 2002, per capita taxed sales will be explained by a model using cigarette price and tobacco control expenditures, as well as a time trend.
4. After 2002, per capita taxed sales data will be higher than estimates from the above model in California and lower in the rest of the nation.
5. Lung cancer mortality rates will follow per capita taxed sales with a time lag of between 16 and 28 years.

Materials and Methods

Smoking prevalence and cigarette consumption

Three population-based survey series provide estimates of smoking prevalence from 1965 to 2008: from 1965 to 2004, there were 24 National Health Interview Surveys (NHIS) with annual household sample sizes of 35,000 to 45,000 and reported response rates of ~80% (14). Although the NHIS public use data are designed to provide regional estimates, identifiers for major states such as California were made available to us. From 1992

through 2007, we examined six Tobacco Use Supplements to the Current Population Survey (TUS-CPS) with monthly sample sizes of ~70,000 to 80,000, and five of these TUS combined three independent monthly CPS samples within a single year. The TUS-CPS provides state-specific smoking estimates with response rates of >65% (2, 25). Both the NHIS and TUS-CPS have an initial household visit, with follow-up by telephone interview. We also report data from 19 surveys conducted between 1990 and 2008 by the Behavioral Risk Factor Surveillance System (BRFSS), an annual random-digit dial telephone survey conducted by state health departments in collaboration with the Centers for Disease Control and Prevention (26). As with other telephone surveys, BRFSS response rates have declined significantly to ~35% in recent years (26). These surveys include a minimum of 2,000 respondents per state per year, although California has significantly supplemented this sample. Following methodology established by the Centers for Disease Control and Prevention (27), prevalence estimates were adjusted for underreporting by nondaily smokers for surveys before a change in question wording (1996 for BRFSS and 1992 for NHIS). We use only self-report data for both prevalence and consumption. The 2000 TUS-CPS did not ask about consumption levels. Smokers in all other surveys were asked to estimate the number of cigarettes they smoked each day. Before 1992, few national surveys distinguished between nondaily and daily smokers. After then, nondaily smokers were asked to report the number of days they had smoked in the previous 30 days, and the average number of cigarettes smoked on the days they smoked; average daily consumption was calculated as (no. days smoked in last 30 days × no. cigarettes smoked on days when smoked)/30.

State-taxed cigarette sales

Data on state-taxed cigarette sales were obtained from the "Tax Burden on Tobacco," which lists cigarette taxes paid to state governments (28). To obtain estimated annual per capita sales, we divided state-taxed cigarette sales by the annual estimated population of adults (18+ years) for each state (29). We aggregated the data for states other than California to obtain the data for the rest of the nation. However, three states implemented their first state cigarette tax after 1960 and before 1971: Colorado in 1965, Oregon in 1967, and North Carolina in 1970. Hence, over this period, we imputed state-taxed sales for the rest of the nation using an adjustment to federally taxed sales. Not all cigarettes sold are subject to state sales tax (e.g., sales in military commissaries and on Indian reservations), and so we subtracted the average annual excess of federal-taxed sales over state-taxed sales for 1970 to 1975 (using all states) from the federal-taxed sales for the years 1960 to 1970. We then subtracted the reported California taxed sales to obtain estimated taxed sales for the rest of the nation for 1960 to 1970.

Cigarette price

Each state's annual average cigarette price is reported in the "Tax Burden on Tobacco" as a weighted average price per pack estimated from a survey of retailers conducted on November 1 of each year. Although detailed survey methods are not available, the estimated price in California has been validated against self-reported cigarette price for 2 survey years (30).

Strength of tobacco control measures

Annual national tobacco control expenditures have been reported for 1990 to 2000 (31), and annual state-specific and national expenditures are available since 2000 through a national tobacco control advocacy group (32). We obtained tobacco control expenditures for California from the health department for each year from 1990 to 1999. To obtain estimates for the rest of the nation in each year, we subtracted total expenditures in California from the national data. Using census estimates for the relevant population in each year, we converted all data to annual per capita expenditures.

Lung cancer mortality

The lung cancer mortality rates are from the Surveillance, Epidemiology, and End Results (SEER) program death certificate data maintained by the National Center for Health Statistics (33). The age-adjusted lung cancer mortality rates of 35 years or older were calculated using the SEER*Stat program and standardized in each calendar year to the 2000 U.S. Census population. The SEER recodes were used for changes from ICD-8, ICD-9, and ICD-10 (34).

Statistical analyses

All computations were carried out using SAS (version 9.2) statistical software. For each survey series and year, we plotted smoking prevalence for California and for the rest of the nation, and summarized time trends shown by these combined data points using simple linear regression. For each year, we plotted the reported state-taxed per capita sales for California and for the rest of the nation. Percent differences for each survey year and for the annual taxed sales data were computed as $100 \times (US - CA)/US$. For the combined survey data, we smoothed these percent differences using a Loess smoother and noted change points at 1989 and 2002. We used simple linear regression on the smoothed survey data and on the raw taxed sales data to summarize time trends for the periods 1960 to 1988 and 1989 to 2002. We carried out this same analysis using the survey estimates of consumption for each year in which survey data were available. We again fitted a linear regression for the time points 1960 to 1988 and 1989 to 2002. We modeled the per capita taxed sales data for California and the rest of the nation using both price and program variables adjusted to year 2000 constant dollars (35), for the period 1960 to 2002. We used this model to project expected taxed sales from 2002 to 2008, the period in

which the survey data and the taxed sales data suggested different trends.

Results

Trends in smoking prevalence

A linear model provides a reasonable fit to the smoking prevalence estimates for both California and the rest of the nation from the combined survey series (Fig. 1A). In 1965, smoking prevalence was higher in California than in the rest of the nation. Since then, smoking prevalence has declined consistently, with prevalence in California declining faster (0.74 percentage points per year; $R^2 = 0.96$) compared with the rest of the nation (0.53 percentage points per year; $R^2 = 0.96$). Smoking prevalence in California fell below the rest of the nation in 1971. Projecting the linear trend to 2010 yields an estimated smoking prevalence of 9.3% in California, about half that of the rest of the nation (17.8%).

Per capita taxed sales of cigarettes

In 1960, taxed sales in California were 212 packs/adult person/year (ppy), which was 14% higher than the rest of the nation (Fig. 1B). California per capita sales remained higher until 1967, after which they dropped, for 3 years, to the same level as the rest of the nation (179 ppy) and the crossover occurred in 1971. From 1974, California taxed sales began a continuous annual decline that was maintained through 2008. A similar consistent decline did not start in the rest of the nation until 1981.

Differences in cigarette consumption

The annual percent difference between California and the rest of the nation in per capita cigarettes consumed shows an increasing trend over time, whether computed from taxed sales or from population survey data (Fig. 2). From 1970 to 1988, the data from both sources show a consistent increase that is well described by a linear trend ($R^2 = 0.98$). According to the taxed sales data, the gap in consumption grew at a rate of 1.15 percentage points per year, whereas the survey data suggested an annual rate of 0.99 percentage points. By 1988, the taxed sales estimate suggests that Californians smoked 22% fewer cigarettes per capita than residents of the rest of the nation, only slightly higher than the 18% difference suggested by the survey data.

Between 1989 and 2002, a linear fit to the taxed sales data ($R^2 = 0.98$) indicated that the gap widened by 2.06 percentage points per year, 78% faster than during the 1970 to 1988 period. A linear fit to the survey consumption data ($R^2 = 0.99$) estimated that the gap widened by 2.26 percentage points per year, within 10% of the taxed sales estimate. Both sets of data estimate that by 2002, Californians consumed about half the cigarettes per capita as the rest of the nation. From 2002 to 2008, the taxed sales data indicated a small decline in this consumption gap, from 52% to 48%. In absolute numbers, in 2008, Californians purchased 40 state-taxed packs per capita

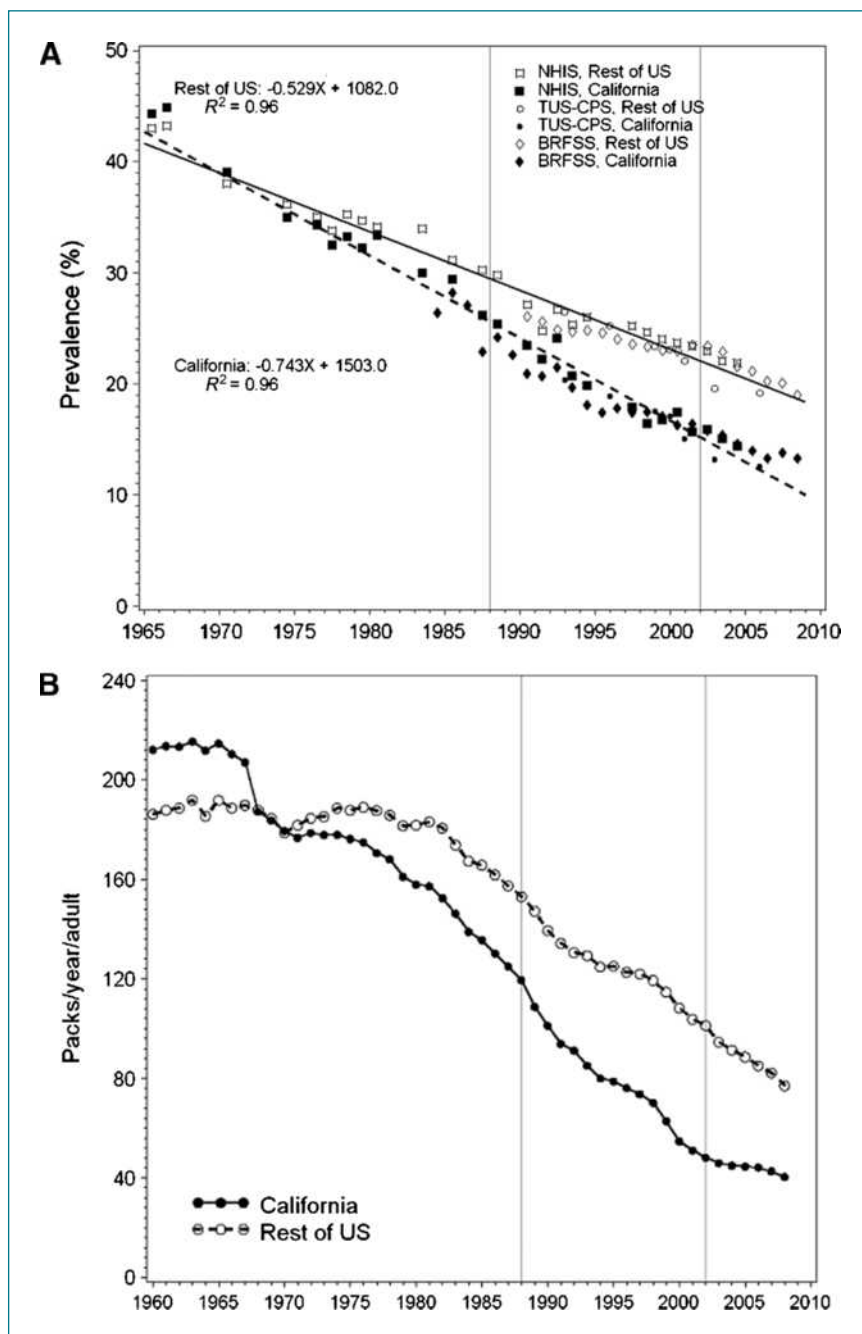


Figure 1. A, smoking prevalence estimates for California and the rest of the nation from three separate national surveillance systems: 1965 to 2007. B, per capita state-taxed sales for California and the rest of the nation: 1960 to 2007.

compared with 77 state-taxed packs per capita in the rest of the nation. Although there are fewer data points, the survey data suggest that the gap between California and the rest of the nation continued to increase so that by 2008, consumption in California was 66% lower than the rest of the nation.

Differences in cigarette price and tobacco control expenditures

In 1960, California's cigarette price was lower than the national average by 3.45%, but by 1965, it had dropped

15% lower (Fig. 3A). Large price increases in California occurred in 1967, 1977, 1989, and 1999. After each respective increase, the average price in the rest of the nation slowly caught up to that in California.

California was the first state to implement a tobacco control program in 1989. Throughout the early to mid-1990s, several national programs spent money on tobacco control and a few other states launched tobacco control programs, including Massachusetts (1993), Arizona (1995), Oregon (1996), Maine (1997), and Florida (1997). In 1999, states received tobacco industry

settlement monies, which many earmarked for tobacco control. The average expenditure on tobacco control in California varied considerably between 1990 and 1999, ranging from just over \$1 to \$3.25 per person (Fig. 3B). California tobacco control expenditure exceeded four times the average expenditure in the rest of the nation for 5 years during the 1990s. From 2000 through 2007, per capita expenditure was on average 20% higher in California than the rest of the nation. After 2007, California expenditure was below the average for the rest of the nation.

Modeling the difference in per capita taxed sales between California and the rest of the nation: 1960 to 2002

We used linear regression to model annual per capita state-taxed sales data from 1960 to 2002 using cigarette price and tobacco control expenditures, both adjusted to constant 2000 dollars, as well as a secular time trend. The model fit the data reasonably well ($R^2 = 0.97$) and estimated that Californians initially smoked 21 ppy more than the rest of the nation (Table 1).

Taxed sales declined significantly over time in both California and the rest of the nation. In the rest of the nation, consumption declined significantly over this period by 1.6 cigarettes/person/year. There was a statistically significant larger time trend in California, 3.3 cigarettes/person/year ($P < 0.001$ for time \times California interaction term). For each \$1 increase in cigarette price implemented in either California or the rest of nation,

taxed sales declined by an average of 12.5 ppy ($P < 0.001$). For each additional \$1 spent on tobacco control interventions, taxed sales declined by an average of 4.5 ppy ($P = 0.01$). We investigated the effect of differences between California and the rest of the nation in the proportion of the population that is of white race/ethnicity, but this effect was not significant in our model and did not affect parameter estimates (data not shown).

We used this model to estimate expected taxed sales from 2002 to 2008 using the reported cigarette price and tobacco control expenditures over this period. For California in 2008, the expected taxed sales from the model were 30.2 ppy, which is 10.2 ppy lower than the number of packs sold on which taxes were collected. For the rest of the nation, the model predicted taxed sales of 90.4 ppy, which was 13.3 ppy more than packs on which taxes were collected, suggesting a 17% loss in taxed sales. From the model, we estimate that in 2008, absent changes in enforcement or tax evasion since 2002, per capita tobacco sales in California would have been 66% lower than in the rest of the nation.

Trends in lung cancer mortality

In the 1970s (Fig. 4), lung cancer mortality rates were higher in California (76.3 deaths per 100,000 persons per year) than the rest of the nation (71.5 deaths per 100,000). California rates peaked in 1987 at ~108.6 deaths per 100,000, after which they declined steadily to 77.1 per 100,000 in 2007, almost the same rate as in 1970. In the rest of the nation, lung cancer mortality increased steadily

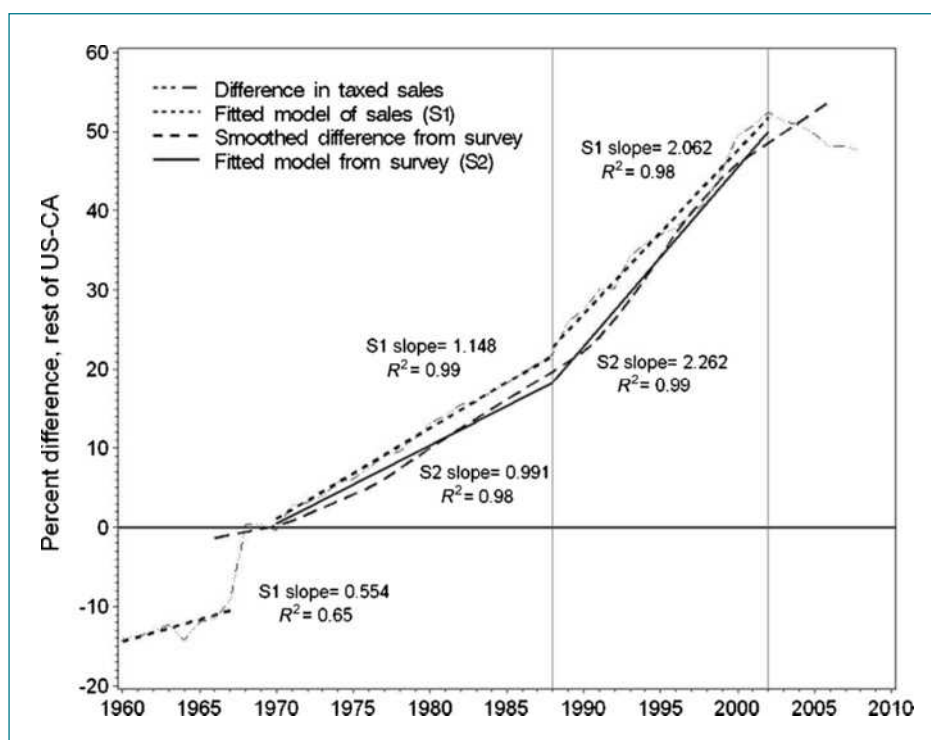


Figure 2. Trends in percent differences in per capita cigarette consumption between the rest of the nation and California: 1960 to 2007.

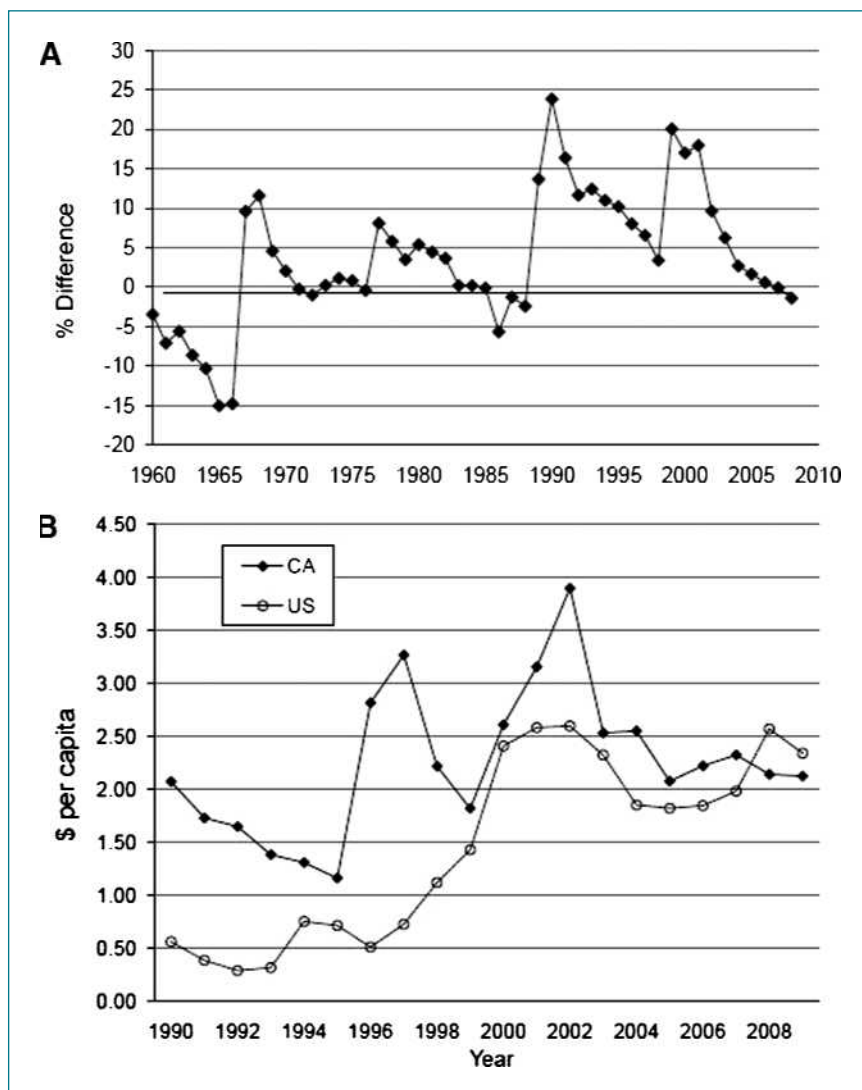


Figure 3. A, percent difference in cigarette price between California and the rest of the nation: 1960 to 2007. B, differences in per capita tobacco control expenditure between California and the average for the rest of the nation: 1990 to 2008.

to peak in 1993 at 116.8 per 100,000. By 2007, the rate had declined to 101.7 per 100,000 (a 24.2% difference with California).

The percent difference in lung cancer mortality between California and the rest of the nation seems to parallel earlier differences in per capita taxed sales (Fig. 5). California lung cancer mortality rates were higher until 1985, 16 years after the California taxed sales first dropped below that of the rest of the nation. Since then, the percent difference in mortality has followed a linear pattern, with the gap increasing at 1.06 percentage points per year ($R^2 = 0.97$)—a very similar slope to that of the earlier per capita taxed sales (slope 1.15 percentage points per year, $R^2 = 0.99$).

Conclusion

Between 1960 and 2002, both per capita taxed cigarette sales data and cigarette consumption estimates from

different national survey series lead to similar conclusions about changes in smoking behavior. Californians initially smoked more cigarettes per capita than the rest of the nation. In 1967, per capita consumption dropped dramatically in California, a decrease associated with the introduction of a California-specific major cigarette price increase (15) and the start of the national antismoking media campaign enabled by the national Fairness Doctrine policy (14, 36). This initial large drop in per capita consumption in California was followed by an 18-year period in which the gap in cigarette consumption consistently widened between California and the rest of the nation. A similar widening gap was observed in lung cancer rates between California and the rest of the nation 16 years later, and by 2007, lung cancer rates in California were 24% lower than the rest of the nation.

After the introduction of the California Tobacco Control Program, the gap in consumption between California and the rest of the nation grew at twice its former rate. By

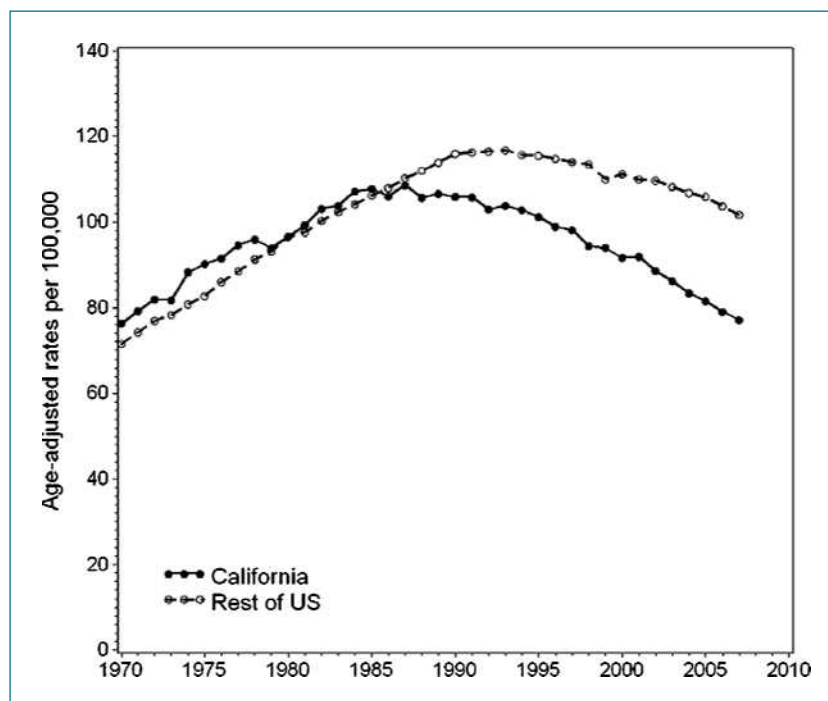
Table 1. Linear regression model of taxed sales as a function of cigarette price, Tobacco Control Program expenditures, and time, California compared with the rest of the nation, 1960 to 2002

	Parameter estimate (95% confidence limits)	P
Intercept	223.1 (213.8 to 232.4)	<0.001
Price/pack, 2000 \$	-12.5 (-18.1 to -6.9)	<0.001
Program expenditure per adult, 2000 \$	-4.5 (-8.0 to -1.1)	0.01
Indicator for California, 1960 offset	21.1 (14.5 to 27.7)	<0.001
Time (y)	-1.6 (-1.8 to -1.4)	<0.001
California-specific time trend (y)	-1.7 (-2.0 to -1.4)	<0.001

2002, Californians consumed half as many cigarettes as the rest of the nation. By contrast, when comparing rates of decline in smoking prevalence between California and the rest of the nation, in this study, we did not find any marked change associated with the start of the program. Nonetheless, there were continuously diverging prevalence rates from 1970, and we estimate that in 2010, the proportion of smokers in California is half of that for the rest of the nation. In previous work, we have identified that part of this decline comes from a major program effect in reducing initiation in the young (37).

It has been suggested that the decline in lung cancer in California in the early 1990s can be attributed to changes in smoking behavior associated with the introduction of the California Tobacco Control Program (8); however, we did not find the lung cancer mortality data to be consis-

tent with this hypothesis. Rather, early declines in California lung cancer mortality rates seem to be due to changes in smoking behavior that predate the Tobacco Control Program. The California lung cancer mortality rates crossed below the rest of the nation 16 years after the taxed sales data did so. Further, after these crossovers, the trends in the difference (California versus rest of nation) were very similar for 18 years. Accordingly, we expect that the doubling of the difference in taxed sales that started with the California Tobacco Program will also be observed in the lung cancer mortality rates over at least the next 10 to 15 years. This should become even more marked with the aging of birth cohorts who responded to the Tobacco Control Program with much lower initiation rates. Given the rates of change in per capita cigarette consumption since the start of the Tobacco

**Figure 4.** Trends in lung cancer mortality between California and the rest of the nation: 1970 to 2007.

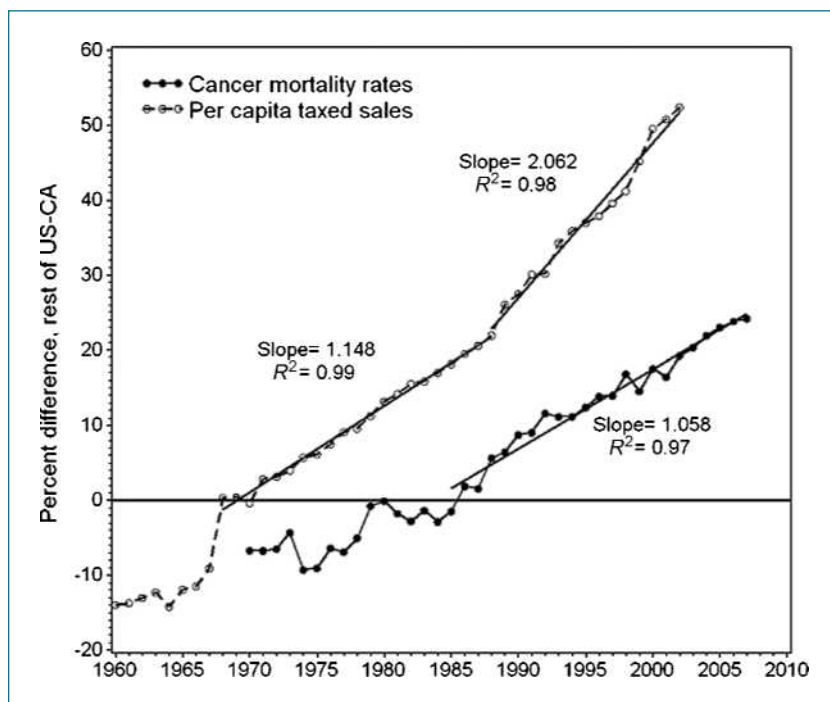


Figure 5. Comparison of percent differences between the rest of the nation and California for per capita taxed cigarette sales and lung cancer mortality.

Control Program, we expect that, over the next 2 decades, the gap in lung cancer mortality between California and the rest of the nation will continue to increase.

We confirmed previous studies (31, 38) indicating that the rates of decline in state-taxed sales in both California and the rest of the nation were well modeled by changes in both cigarette price and tobacco control expenditures, at least until 2002. However, between 2002 and 2008, the state-taxed sales data suggest that the gap between California and the rest of the nation is narrowing, whereas the national survey data suggest no such trend. This recent reversal of a longstanding trend in relative sales was not expected from the level of changes in either cigarette price or tobacco control expenditures. By using a model estimated from the taxed sales from 1960 to 2002 and applied to cigarette prices and tobacco control expenditures from 2002 through 2008, we estimate that the taxed sales in California were 10.2 ppy higher than would have been expected without the increased enforcement measures enacted in 2002. For the rest of the nation, there seems to have been a 17% increased loss in taxed sales. These preliminary estimates suggest that, for this recent period, per capita taxed sales may not be a valid marker of smoking behavior.

In 2002, California was the first state to take significant action to strengthen enforcement of retail cigarette tax collections. This included a major increase in enforcement staff (39). After these changes were introduced, a significant gain in tax receipts was reported (40). Further, California was not one of the many states that markedly increased their excise taxes since 2002. The variation in cigarette prices reported across states was less than

\$1.80 before 2002; after which, it increased considerably to be \$3.37 by 2008 (28). This rise in the price differential across states increased the incentives for tax avoidance across the rest of the nation (23). Since 2002, several reports indicate greater tax evasion in states with higher prices (23, 24). Population surveys also suggest differential tax evasion. In 2005, 3.8% of California smokers indicated that they usually bought their cigarettes from non-state-taxed sources (41). New York smokers reported a much higher rate of tax evasion in 2006, with 10% reporting always and 17% sometimes evading state taxes on cigarettes (42).

Survey data are subject to biases such as increased underreporting (36) or undercoverage (43) that could affect estimates of trends in smoking. As social norms against smoking increase and population response rates decrease, these biases could result in inflated trends of decreasing prevalence. Our cross-validation of the differences between California and the rest of the nation using two modes of data suggests that these biases did not significantly distort the survey estimates of trends. Our study uses three national surveys with very different response rates, each of which has been declining over time. However, previous reports have indicated that the decline in response rates is unrelated to smoking behavior (44, 45). Although there is well-known underreporting of cigarette consumption on surveys (when compared with taxed sales), the level of underreporting seems to have been relatively consistent over time (5, 14, 46, 47). Again, as we are comparing California with the rest of the nation, it is only a differential bias that would be problematic. No such differential bias has been reported.

In summary, California responded aggressively to the first Surgeon-General's report on smoking and, since 1970, has had an increasingly lower level of cigarette smoking behavior compared with the rest of the nation. These early differential changes in smoking were associated with preferential declines in lung cancer mortality after a lag of 16 years. The introduction of California's first-in-the-nation comprehensive Tobacco Control Program in 1989 doubled the rate of change in per capita cigarette consumption between California and the rest of the nation, which is expected to translate into further increases in the lung cancer mortality gap over the next 2 decades. However, for the first time in over 20 years, the price of cigarettes in California is not above the median for the rest of the nation, nor is California spending more on tobacco control, suggesting that the current 50% gap in cigarette consumption may start to narrow over the next few years.

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Disclosure of Potential Conflicts of Interest

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