Simulated Effect of Tobacco Tax Variation on Population Health in California

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ABSTRACT

Objectives. This study simulated the effects of tobacco excise tax increases on population health.

Methods. Five simulations were used to estimate health outcomes associated with tobacco tax policies: (1) the effects of price on smoking prevalence; (2) the effects of tobacco use on years of potential life lost; (3) the effect of tobacco use on quality of life (morbidity); (4) the integration of prevalence, mortality, and morbidity into a model of quality adjusted life years (QALYs); and (5) the development of confidence intervals around these estimates. Effects were estimated for 1 year after the tax's initiation and 75 years into the future.

Results. In California, a $0.50 tax increase and price elasticity of –0.40 would result in about 8389 QALYs (95% confidence interval [CI]=4629, 12 113) saved the first year. Greater benefits would accrue each year until a steady state was reached after 75 years, when 52 136 QALYs (95% CI=38 297, 66 262) would accrue each year. Higher taxes would produce even greater health benefits.

Conclusions. A tobacco excise tax may be among a few policy options that will enhance a population's health status while making revenues available to government. (*Am J Public Health.* 2001;91:239–244)

In January 1999, California enacted Proposition 10, an initiative to raise the state excise tax on cigarettes by $0.50 a pack. Several other states have also instated cigarette excise tax increases. Cigarette excise taxes are an attractive public policy tool for 2 reasons. First, they generate substantial revenue for the governmental unit levying the tax. Second, there is substantial evidence that a cigarette excise tax increase will reduce cigarette consumption by motivating some smokers to quit and many others to reduce their daily consumption.[1–9] These behavioral changes may ultimately manifest themselves in improved population health status.[10] In this report, we estimate the health status effects of increases of $0.50 and $1.00 per pack for California residents.

Most models of health outcome emphasize effects on mortality or on life expectancy.[11] However, such studies often underestimate the impact of smoking on public health. In addition to early death, tobacco consumption causes significant and prolonged loss in quality of life through illnesses such as chronic obstructive pulmonary disease.[11] Other models estimate the effect of smoking on specific diseases, such as lung cancer or heart disease, but often fail to account for all the diverse effects of tobacco consumption.[11] Smoking-related problems range from hearing loss to heart disease and a multitude of cancers.[12]

In this analysis, we use a combined index of morbidity and mortality known as the quality adjusted life year (QALY) to demonstrate changes in life expectancy with adjustments for quality of life. In cost–utility analysis, the relative value of medical care is often expressed as the cost per QALY. Typically, QALYs are produced at some cost in available resources. A tobacco excise tax may offer a unique situation in which QALYs are saved while resources are made available to government.

Methods

Overview

On the basis of current literature, we projected the expected changes in smoking prevalence that would result from a range of cigarette tax increases. These estimates were made for 2 points in time: 1 year after the tax was initiated and 75 years into the future, when the effects on the current cohort of smokers and potential smokers would be fully dissipated. Using the Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC) program[13] and quality of life estimates from the National Health Interview Survey (NHIS), we then translated these changes in smoking prevalence into changes in population mortality and morbidity and then into QALYs for the California population.

Elasticity Estimates

Elasticity is a concept economists use to measure responsiveness to price changes. It is calculated as the percentage change in overall demand that results from a 1% change in a good's price. An elasticity estimate of –0.4 indicates that overall demand will decrease 4% in response to a 10% price increase.

An expert panel convened by the National Cancer Institute arrived at a consensus estimate of the adult overall price elasticity of demand for cigarettes of –0.4.[4] Generally accepted estimates[1–6,13–15] range from –0.2 to –0.6 (Table 1). Since the literature[2,9,15] also presents

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TABLE 1—Selected Econometric Estimates of the Price Elasticity of Demand For Cigarettes

Overall Adult Price Elasticity Estimate	
Adult studies	
Lewit and Coate[1]	–0.89
Becker et al.[2]	–0.40 (short run)
	–0.76 (long run)
Keeler et al.[3]	–0.20 to –0.36 (short run)
	–0.46 to –0.58 (long run)
NCI expert panel[4]	–0.3 to –0.5
Hu et al.[6]	–0.3 to –0.4 (short run)
	–0.5 to –0.6 (long run)
Farrelly and Bray[5]	–0.25
Overall Adolescent Price Elasticity Estimate	
Adolescent Studies	
Lewit et al.[7]	–1.44
Wasserman et al.[8]	0.86
Chaloupka and Grossman[9]	–1.31

Note. NCI = National Cancer Institute.

higher adult long-term estimates, in the range of –0.8, we used overall adult demand elasticity estimates of –0.2, –0.4, –0.6, and –0.8 in our models.

While a price increase may encourage current smokers (adults) to quit or cut back, it will also discourage potential future smokers (adolescents or young adults) from starting to smoke. The literature has consistently shown that price elasticity varies inversely with age: younger people appear more sensitive to the price of cigarettes than older people. As a result, estimates of adolescent elasticity of demand can be much higher than the adult estimates, varying from insignificant[8,16] to the more accepted range of –0.8 to –1.2.[7,9,12] (Although the studies that produced nonsignificant estimates of adolescent price elasticity introduced some controversy about the role of price in deterring adolescent smoking owing to limitations regarding their data, the higher estimates are given more weight in the literature.)

We know of no previous studies that have examined the impact of excise tax increases as large as $1.00. However, most studies have examined how price or excise tax differences across states influence patterns of smoking. Such cross-state cigarette price differences can approach $1.00 per pack. For example, in 1996, the average price of cigarettes in North Carolina was $1.52 per pack, while the average price in Massachusetts was $2.45 per pack. Therefore, it is appropriate to use elasticity estimates reported in this literature to simulate the impact of the $0.50- and $1.00-per-pack price increases in California in 1999.

For both adults and adolescents, a change in the price of cigarettes can influence consumption in 2 ways, both of which are captured in the estimate of overall elasticity of demand. First, a change in price can affect smoking prevalence: the number of individuals who decide to become smokers or to quit smoking. This is quantified as the elasticity of smoking participation. The literature generally agrees that the elasticity of smoking participation represents about half of overall elasticity of demand among adults and about 60% to 80% of overall elasticity among adolescents.[2,7,9] Thus, for instance, an overall estimate of adult elasticity of demand of –0.4 would imply an adult elasticity of participation of approximately –0.2. In our modeling, we assumed throughout that adult participation elasticity was 50% of overall adult elasticity of demand and that adolescent participation elasticity was 70% of overall adolescent elasticity of demand.

Second, a change in cigarette prices can influence the number of cigarettes consumed. This is the conditional demand elasticity (i.e., conditional on being a smoker). Because modeling changes in consumption is much more complicated than modeling changes in prevalence, the initial work we report here made the conservative assumption that consumption levels among those who continued to smoke did not change as a result of a price increase. In light of evidence showing that smokers facing higher taxes (prices) smoke cigarettes higher in tar and nicotine—thereby mitigating or removing altogether any beneficial health effects for continuing smokers from a tax increase[17]—we consider this assumption appropriate, since it produces the equivalent result of no health benefit increase for continuing smokers.

Model Cases and Assumptions

We calculated figures for 3 scenarios. Two of these scenarios use adult elasticities for overall demand and 1 uses adolescent elasticities. Using the adult estimates discussed above for overall elasticity of demand of –0.2, –0.4, –0.6, and –0.8, with a 50% portion attributed to elasticity of participation, we considered the effect of a tax increase (a) 1 year into the future and (b) 75 years into the future. Using the adolescent estimates for overall elasticity of demand of –0.8, –1.0, and –1.2, with a 70% share attributed to participation, we also considered the effect (c) 75 years hence. We selected the time point of 75 years into the future because it is reasonable to assume that by then everyone 85 or younger would have been subject to the increased tax during the years they initiated smoking.

For case a, we assumed that only some smokers will quit immediately (cessation) and that within each age group of adult smokers the same percentage will do so; we made no assumption of a change in initiation. For both our 75-year cases, we assumed that the effect of the 1999 tax increase manifests itself entirely in lessened initiation. Smoking initiation occurs almost exclusively among adolescents, and the prevalence among any age group whose adolescence occurred subsequent to the tax increase would reflect the reduced initiation that would result from higher prices and greater price sensitivity among teens. Thus, for our 75-year estimates, we compared the effect assuming adult elasticity estimates (case b) with that using adolescent elasticity estimates (case c).

For our adult elasticity cases (a and b), we examined 6 subcases: 3 with a tax increase of $0.50 and 3 with an increase of $1.00. For the $0.50 increase, we simulated results for overall elasticities of demand of –0.20, –0.40, and –0.60. For the $1.00 increase, we used –0.4, –0.6, and –0.8. The combination of a $0.50 increase and an overall elasticity demand of –0.8 was not used, since it yields the same results as a $1.00 increase with an overall elasticity of demand of –0.4. Similarly, the $1.00 increase with a –0.2 overall elasticity of demand was not used, because it is equivalent to the $0.50 increase with a –0.4 overall elasticity of demand. For these adult elasticity cases, we used the $0.50 increase with –0.4 overall elasticity of demand as our basis for comparison (our "base case").

For our adolescent elasticity case (case c), we looked at 6 subcases: the $0.50 and $1.00 tax increases each with an overall demand elasticity of –0.8, –1.0, and –1.2. Table 2 shows the expected changes in tobacco consumption based on the various assumptions of tax increase and elasticity. For the adolescent elasticity case, our base case was the $0.50 tax combined with a –1.0 overall elasticity of demand.

To derive our 75-year estimates in cases b and c, we assumed that the 1999 tax would be adjusted as necessary for inflation (or deflation) over time. Both cases also assume constant population size and composition over the

TABLE 2—Relation Between Tobacco Tax Increases and Estimated Changes in Tobacco Use, by Case

Simulation Run	Tax Increase, $	Increase/Price	Elasticity	Change in Overall Demand	Participation Elasticity[a]	Change in Use (a) or Initiation (b)[b]	Change in Participation Use[c]
Cases a and b: adult elasticities[d]							
1	0.50	0.20	–0.2	–0.04	–0.1	–0.02	
2	0.50	0.20	–0.4	–0.08	–0.2	–0.04	
3	0.50	0.20	–0.6	–0.12	–0.3	–0.06	
4	0.50	0.20	–0.8	–0.16	–0.4	–0.08	
2a	1.00	0.40	–0.2	–0.08	–0.1	–0.04	
4a	1.00	0.40	–0.4	–0.16	–0.2	–0.08	
5	1.00	0.40	–0.6	–0.24	–0.3	–0.12	
6	1.00	0.40	–0.8	–0.32	–0.4	–0.16	
Case c: adolescent elasticities							
1	0.50	0.20	–0.8	–0.16	–0.56		–0.112
2	0.50	0.20	–1.0	–0.20	–0.7		–0.14
3	0.50	0.20	–0.12	–0.24	–0.84		–0.168
4	1.00	0.40	–0.8	–0.32	–0.56		–0.224
5	1.00	0.40	–1.0	–0.40	–0.7		–0.28
6	1.00	0.40	–1.2	–0.48	–0.84		–0.336

[a]For case c, participation elasticity = 0.70 of total demand elasticity.
[b]In case a, change is in use, while in case b, change is in initiation.
[c]In case c, change in use rate in the future is a function of change in initiation rate.
[d]Subcase 2a is not distinct for purposes of analysis from subcase 2, since both result in the same percentage change in participation; this is also true for subcases 4a and 4.

75-year period. We recognize that population size will change, but we kept it constant so that the output could be interpreted in relation to current benchmarks. We also assumed that 75 years hence, the effect of a tax increase in 1999 would be to decrease the number of former smokers at that future time relative to what their number would have been without the tax increase by the same percentage as such a presently imposed tax increase would reduce the future number of current (i.e., 75 years hence) smokers relative to its nonintervention level.

For all cases, we used an average cigarette price per pack in California of $2.50. We also assumed that the tax increase would be completely passed on as a price increase. Thus, a $0.50 tax increase would represent a 20% price increase. With an assumed elasticity of –0.2, for example, the overall change in smoking demand would then be –4%.

Estimating Mortality Effects

The effects of changes of smoking prevalence on population mortality were estimated with SAMMEC software, available from the Centers for Disease Control and Prevention (CDC).[13] Version 3.0 can estimate 3 outcomes: smoking-attributable mortality, years of potential life lost (YPLL), and indirect mortality costs. Our model uses the YPLL component.

SAMMEC uses attributable risk formulas to estimate the number of deaths from neoplastic, cardiovascular, respiratory, and pediatric diseases, together with burn deaths, associated with cigarette smoking. SAMMEC requires 4 types of data as input: (1) mortality figures from the population of interest for a given year, broken down by sex, age, and *International Classification of Diseases, Ninth Revision* (*ICD-9*) classification, for which we used 1996 mortality data from California state vital records; (2) smoking prevalence figures by sex, smoking status (current vs former), and age (35–64 vs ≥65 years) and among pregnant women, which we derived from the 1996 California Tobacco Survey[18]; (3) population estimates by sex and 5-year age category, for which we also used 1996 California Tobacco Survey figures; and (4) YPLL due to smoking-related diseases, the calculation of which requires as input average years of life remaining, by sex, for each 5-year age category of the study population; for this, we used SAMMEC-supplied 1991 US figures.

Estimating Quality of Life Effects

To represent outcomes, we applied a comprehensive model of health-related quality of life.[19–23] With data from the 1994 NHIS, we estimated the morbidity consequences of smoking by using the Health and Limitations Index measure of years of healthy life. To estimate QALYs, we used the method of Erickson et al. that was developed by the National Center for Health Statistics, CDC.[24] The method requires 4 sources of information. The first source, life expectancy, is described above. Two other types of information, activity limitation and perceived health, come from the NHIS. Activity limitation describes performance of social role. In the NHIS, questions are contingent on a particular age group and are answered within this context for those who are working, homemaking, going to school, or retired. Each individual is classified into 1 of 6 categories on the basis of age and performance of major activity.

In addition to this classification by activity level, each respondent in the NHIS is asked to rate his or her perceived health status, in response to the question "Would you say your health, in general, is excellent, very good, good, fair, or poor?" The 5 levels of response to this question are factorially combined with the 6 levels of functional limitation to form a matrix with 30 cells. Each respondent in the NHIS is classified into 1 of these 30 categories.

The fourth source of information is used to assign a value to each of the 30 states on the continuum, ranging from death (0.0) to optimum functioning (1.0). The values are assigned by multiattribute utility scaling.[25] Each of the 30 states was matched to values corresponding to similar states as estimated by the Health Utilities Index.[26,27] Survival time for current, former, and never smokers was adjusted for quality of life as estimated by this index. The calculations were performed separately for men and women and adjusted by age.

To develop confidence intervals, Monte Carlo simulation was performed with the Crystal Ball 4.0 software program (Decisioneering Advanced Analytic Tools, Denver, Colo). For simulation purposes, we consider it highly plausible to assume that QALYs are normally distributed. Each simulation used 10 000 trials.

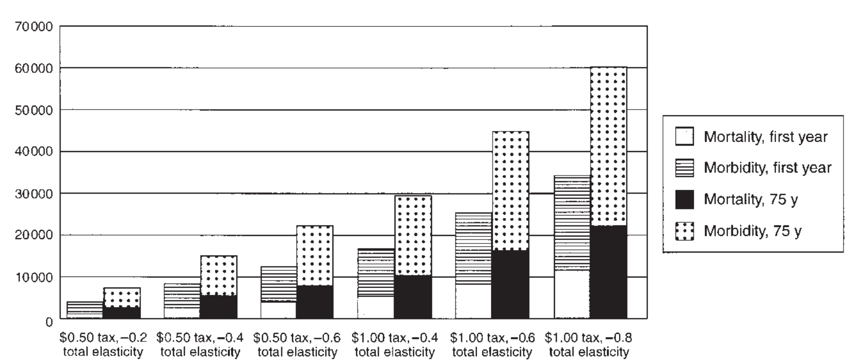
Results

Under the base case of an 8% decline in overall demand for cigarettes, 2714 years (95% confidence interval [CI]=2332, 3098) of potential life would be gained annually. Projecting 75 years forward (case b), the conservative estimate suggests that 5414 life years (95% CI=4568, 6328) will be saved per year in the base case. Assuming that the tax increase works primarily to deter youth from smoking, and looking 75 years into the future (case c), the base model suggests that 18 811 life years (95% CI=15 920, 21 920) will be saved each year. Under case a, which considered changes in smoking demand of between 4% and 32%, the increase in life years ranged from 1136 to 11 477 per year. Under case c, which considered a steady state and used a range of overall demand reduction of from 16% to 48%, the yield in life years ranged from 14 828 to 47 641 annually.

Using data from the NHIS, we also estimated the effect of a change in smoking status on health-related quality of life for individuals in age categories ranging from 18 to 19 years through 85 years and older. For women at each age, current smokers have lower scores on health-related quality of life than former or never smokers. After age 25, a similar pattern is seen for men. Beyond age 40, never smokers tend to have higher scores than former or current smokers.

Total QALYs were estimated by combining weighted YPLL (mortality) with quality of life (morbidity). The base case model suggests that in the first year the $0.50 tax would produce approximately 4321 QALYs per year for men and approximately 4067 QALYs per year for women in case a. For case b, 9254 QALYs per year would be produced for men and 5681 per year would accrue for women. Case c in the base scenario assumes an elasticity of demand of –1.0 and shows an outcome of 32 158 QALYs per year for men and 19 979 per year for women.

Figure 1 summarizes the yield in QALYs under different tax and adult elasticity assumptions. Reductions in tobacco consumption result from 2 sources, improved life expectancy and improved health-related quality of life. Our simulations suggest that about two thirds of the benefits reflect changes in quality of life and one third reflects changes in mortality. This is shown in Figure 1, which portrays the mortality and morbidity component of total annual QALYs saved given the various tax increase and elasticity settings under adult elasticity assumptions. The height of each column shows total QALYs gained, while the bottom section of each column shows the decrease in YPPL. Under the assumption of a $1.00 tax and a –0.60 elasticity, the model suggests that about 25 380 QALYs (95% CI=14 279, 36 334) would be produced in the first year. Under case b, the annual QALY yield would be about 44 695 (95% CI=32 705, 56 971), while under case c, if an adolescent elasticity of –1.0 is assumed, it would be about 105 673 QALYs (95% CI=76 830, 134 748), as shown in Figure 2. Since we are not comparing a present economic cost with a future anticipated benefit, discounting seems inappropriate, but for comparison purposes the latter 2 totals would become 4867 and 11 508 per year, respectively, under the 3% rate recommended by Gold et al.[28] and 1153 and 2726 per year under a 5% discount. These totals would produce 10 950 and 25 880 QALYs saved annually per million present-day smokers in California, respectively.



Note. Mortality and morbidity components of QALYs are shown separately.

FIGURE 1—Total annual gains in quality adjusted life years (QALYs) (column height) by assumed tax increase–elasticity combination for adult elasticities (cases a and b).

Discussion

In 1999, as a result of 2 separate $0.50-per-pack increases, smokers in California experienced an increase in the price of premium brand cigarettes amounting to at least $1.00 per pack. The first increase occurred with the implementation of the additional $0.50-per-pack tax on cigarettes, along with taxes on other tobacco products, which resulted from California voters' approval of Proposition 10. The second $0.50-per-pack increase resulted from the tobacco industry's response to the provisions of the Multistate Master Settlement Agreement. By the terms of this agreement, which California signed soon after Proposition 10 was passed, the tobacco industry will pay California and 45 other states $206 billion over the next 25 years. Unlike earlier settlement proposals, this one did not mandate any increases in the price of cigarettes or other tobacco products. However, by late November 1998, the 2 largest US cigarette manufacturers had announced their intention to raise the price of its premium brand cigarettes by $0.45 per pack to offset the settlement costs. (Owing to coupon redemption programs and carton price decreases, California smokers could potentially avoid the industry-driven price increases.) Distributors and retailers generally added an additional $0.05 to the wholesale price increase, so consumers realized a full $0.50-per-pack increase due to the settlement.[29,30] On top of the excise tax increase and the retail price increase driven by the agreement, the tobacco industry announced a further $0.22-per-pack increase in the price of cigarettes in late 1999. Therefore, even with new marketing approaches that use coupons and other incentives, California smokers faced an unprecedentedly large increase in cigarette prices in 1999.

Even in California, with one of the lowest smoking rates in the nation, the 1999 $0.50-per-pack tax increase is expected to generate about $700 million a year in revenues. In addition to these tax-generated revenues, the reductions in tobacco use that result from both the increased excise taxes and the industry-driven price increases will also produce an eventual savings by reducing the cost of providing health services for adults with tobacco-related chronic

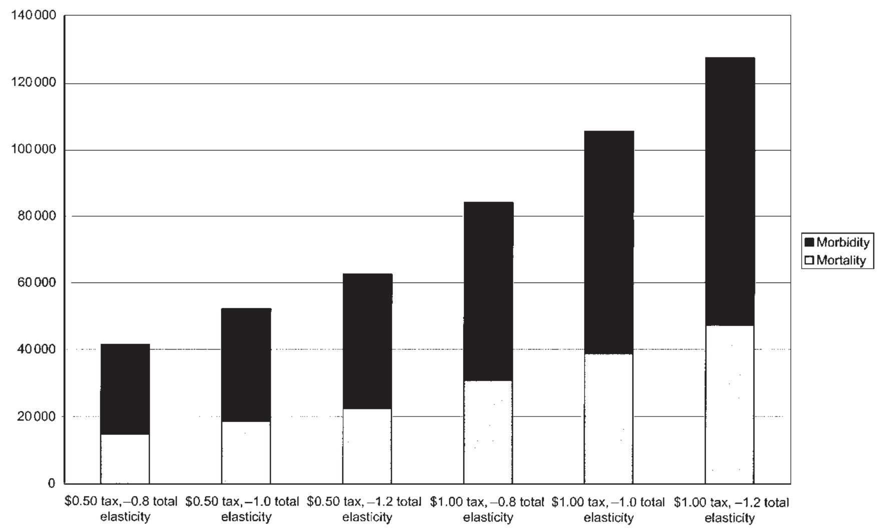


FIGURE 2—Total annual gains in quality adjusted life years (QALYs) by assumed tax increase–elasticity combination for adolescent elasticities (case c), showing mortality and morbidity components.

illnesses.[31,32] Despite decades of public health efforts and declining US smoking rates, the use of tobacco products remains a widespread problem. McGinnis and Foege estimated that tobacco was responsible for about 19% of approximately 2 150 000 deaths in the United States in 1990.[11] The World Health Organization projects that, worldwide, there will be 10 million tobacco-related deaths per year by 2030.[33]

Previous analyses may underestimate the impact of tobacco use by disregarding morbidity. The most widely cited analyses by Warner,[10] Manning et al.,[34] and Harris[35] all consider mortality, but not morbidity. Those studies that consider morbidity often estimate only the economic costs of smoking-related illnesses[31,36] or smoking-related health care use. Importantly, our results also probably underestimate the potential improvements in QALYs due to reduced smoking because we focus on participation (via initiation or cessation) and ignore benefits that might accrue to those who continue to smoke but reduce the number of cigarettes they consume. Doll and Peto estimated the incidence of lung cancer as a function of the number of cigarettes smoked[37]; to expand this analysis to include all smoking-related diseases is beyond the scope of this report. Nonetheless, the omission of the health impact of reduced cigarette consumption among smokers is likely to bias our results downward.

Another important finding from the present study was that the public health benefit of a tobacco tax increase grows for each of the first 75 years following its inception. This happens because a higher tax will significantly reduce initiation of the smoking habit among adolescents. Since smoking is rarely initiated among adults, the effect serves to reduce the pool of people who will later develop smoking-related diseases. A broad time perspective is needed to fully appreciate the benefits of the tax. It might be argued that many smokers over the age of 40 are confirmed, addicted users who are unlikely to change their habits in response to a tax. Cases b and c recognize this possibility by representing the effect of the tax to be on initiation rather than cessation. Further, some recent evidence suggests that the number of hard-core, addicted smokers is small.[38] This suggests that smokers throughout the life cycle may be responsive to quitting incentives. If this is true, our results are even more conservative.

Several other important limitations of our analyses must be considered. One potential problem is that we used national estimates of elasticity, even though our inferences apply to California. This was necessary because there has been only 1 study of the impact of the California tobacco tax.[3] However, this study offered elasticity estimates near the median for all studies. Thus, using elasticity estimates specific to California would not have substantially affected the results, and using national estimates may make our generalizations more robust.

Our analyses assumed that differences in self-reported health status between smokers and nonsmokers are attributable to smoking. It is possible that other health habits contribute to these differences. Unfortunately, the NHIS has few data on other health habits. In our data, adjustment for socioeconomic status, a crude proxy for health habits, did not eliminate the difference. Peto et al. have argued that all differences between smokers and nonsmokers are appropriately attributed to tobacco use.[33] However, we must recognize that our estimates may be inflated because smokers also tend to have other unhealthy health habits.

In summary, the motivation for health policy is to save lives and improve the health of the nation. It is often assumed that the best way to accomplish this goal is to invest in medical care. Tobacco tax programs may be unique in that they produce substantial public health benefits and at the same time produce revenues that might be used for other public health programs. Although the benefits we estimated appear small, compared with those of other preventive interventions, the tax increase clearly emerges as one of the best public health alternatives. Further, our findings suggest that the public health benefits of the California tobacco tax will grow stronger the longer the tax increase has been in effect. We believe that these estimates are conservative. Indeed, the elasticity values used in our base case were lower than those used in other recent analyses.[39] Near-term evaluations may misstate the full impact of the tobacco tax because elasticities are larger for those who are young and not using or not addicted to tobacco. Cases b and c in our models suggest that the impact of the tax will grow with the duration of time since the initiation of higher prices. The large future benefits suggested in case c are realistic given current data. ☐

Contributors

R. M. Kaplan designed the analysis, wrote the original grant proposal, and developed the conceptual model for the studies. C. F. Ake was the primary data analyst; he generated the computer runs, developed the mortality model, and computed the confidence intervals. S. L. Emery was also actively involved in the execution of the analysis and developed the economic components of the paper; she contributed the sections on elasticity and economic evaluation. A.M. Navarro worked on the estimates of QALYs by using the NHIS database. All authors contributed extensively to the writing and rewriting of the manuscript and systematically reviewed the analysis.

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