RESEARCH PAPER

The economic burden of smoking in California

W Max, D P Rice, H-Y Sung, X Zhang, L Miller

Tobacco Control 2004;**13**:264–267. doi: 10.1136/tc.2003.006023

See end of article for authors' affiliations

Correspondence to: Professor Wendy Max, Institute for Health & Aging, University of California, San Francisco, 3333 California Street, Suite 340, San Francisco, CA 94118, USA; wmax@itsa.ucsf.edu

Received 5 September 2003
Accepted 15 March 2004

Objective: To develop estimates of the direct and indirect costs of smoking for California in 1999.
Methods: A prevalence based approach was used to estimate the annual costs of smoking. Econometric models were used to estimate the smoking attributable fraction (SAF) for direct costs (hospitalisations, ambulatory care, prescription drugs, home health care, and nursing home services) and indirect costs due to lost productivity from smoking related illness. The models controlled for socioeconomic factors and other risk behaviours. Epidemiological methods were used to estimate the SAF for indirect costs due to lost productivity from premature deaths. The SAFs were applied to total health care expenditures, days lost, and deaths to obtain smoking attributable total costs.
Results: In 1999, the total costs of smoking in California were $15.9 billion, $475 per resident, and $3331 per smoker. Direct costs were $8.6 billion (54% of the total), indirect costs due to lost productivity from illness were $1.5 billion (10%), and indirect costs due to premature deaths were $5.7 billion (36%). The cost of smoking was $9.4 billion for men and $6.3 billion for women. There were 43 137 deaths attributed to smoking, representing a total of 535 000 years of life lost. The value of life lost per death averaged $132 000, or 12.4 years.
Conclusions: California smoking related costs are high. The cost methodology presented is useful for other states and nations interested in estimating their costs of smoking. Cost estimates can be used to evaluate the level of cigarette taxes and other policies related to smoking.

Cigarette smoking is a major public health problem. It is the leading cause of preventable death in the USA and in California.[1] Each year approximately 440 000 Americans die from cigarette smoking—one out of five deaths.[2] The toll of smoking related deaths in California is similar. More than 43 000 people (25 000 men and 18 000 women) in the state died from smoking related causes in 1999, comprising 19% of all deaths in California. In addition to premature deaths, cigarette smoking also causes illness, disability, and productivity losses.

The health hazards of cigarette smoking have been well documented, beginning with the 1964 landmark report of the Surgeon General of the USA.[3–10] Over the years, this growing scientific knowledge base has contributed to a substantial decline in smoking. In 2002, 23.1% of the adult population 18 years of age and over in the USA smoked cigarettes, down from 41.9% in 1965. However, adult smoking prevalence differed more than twofold across states (from 12.7% in Utah to 32.6% in Kentucky), with a rate of 16.4% in California.[11]

Many tobacco control activities take place at the state or local level. California leads the nation in tobacco control activities, but 4.7 million Californians still smoke. It is essential that legislators and activists have the latest cost data to use as a basis for continued support for tobacco control efforts, as emphasised in the latest Master Plan of the Tobacco Education and Research Oversight Committee.[12] The goal of this study is to present estimates of the direct and indirect costs of smoking for California in 1999.

METHODS

To view Methods go to http://www.tobaccocontrol.com/supplemental

RESULTS

Smoking prevalence rates for California adults aged 18 and older in 1999 are shown in table 1. More men than women smoked: 2.7 million men and 1.9 million women. About 6.2 million additional Californian adults were former smokers, who may continue to experience the adverse health effects of smoking. Table 1 also contains the smoking attributable fractions (SAFs) for direct costs and indirect costs by sex. Except for the indirect costs of lost productivity due to smoking related illness, the SAFs are substantially smaller for women than for men—11.4% of direct costs for men and 8.0% for women are attributable to smoking. Smoking accounts for 22.2% of deaths for men and 15.8% for women.

Total costs

The total costs to California of the health effects of smoking in 1999 amounted to $15.8 billion, equalling $475 per resident and $3331 per smoker (table 2). The direct costs represented 54% of the total, indirect lost productivity due to illness was 10%, and indirect lost productivity due to premature death was 36%.

The cost of smoking for men was $9.4 billion compared to $6.3 billion for women. However, the comparison differs by type of cost. Women have similar direct health care costs as men. While fewer women smoke, women tend to be heavier users of the health care system in general and they tend to live longer than men. Men and women had nearly equal lost productivity from illness; men had higher earnings, but women missed more days from work on average. Lost productivity from premature death was 3.5 times as great for men as for women because more men die of smoking related illness and men are paid more in the labour market and thus have greater lost earnings. On a per resident basis, the total cost for men was almost 50% higher than for women; on a per smoker basis, costs for men were only 6% higher.

Direct costs

Direct costs were $8.6 billion, with almost half of these costs (47%) going for hospital care, 24% for ambulatory care, 15%

Abbreviations: CDC, Centers for Disease Control and Prevention; SAF, smoking attributable fraction

Table 1 Adult population, smoking prevalence, and smoking-attributable fractions of medical expenditures, California, 1999

	Total	Men	Women
Population ('000)	24222	12000	12222
Smoking prevalence:			
Current smokers (%)	18.7	22.1	15.3
Former smokers (%)	25.8	28.9	22.8
Smoking attributable fractions (%):			
Direct cost	9.3	11.4	8.0
Ambulatory	5.2	7.1	4.1
Prescriptions	10.0	13.0	8.3
Hospital	12.0	13.6	10.6
Home health	4.5	6.1	4.0
Nursing home	23.0	25.4	21.8
Indirect lost productivity			
Work loss days	NA	8.0	8.9
Bed disability days	NA	NA	15.5
Premature deaths	NA	22.2	15.8

NA, not available.

for nursing home care, 13% for prescriptions, and 1% for home health services. Smoking attributable costs for men exceeded those for women for hospitalizations and ambulatory care, while costs for women were greater than those for men for nursing home care, prescriptions, and home health care.

Lost productivity due to illness and premature death

Productivity losses due to smoking related illness in California amounted to $1.5 billion in 1999, indicating that smokers lost many days from productive activities. Losses amounted to $276 per male smoker and $381 per female smoker.

There were 43 137 deaths attributed to smoking, accounting for 18.9% of all deaths in California in 1999. The value of lost productivity from smoking related deaths in 1999 dollars was $5.7 billion. The value of life lost per death averaged $132 000; total years of life lost amounted to 535 000 years or 12.4 years of potential life lost per death.

The leading cause of smoking attributable death was cardiovascular disease, accounting for 17 137 premature deaths. There were 14 290 and 11 290 deaths due to neoplasms and respiratory diseases, respectively. Non-smokers also died as a result of smoking in California, including infants exposed in utero (68 deaths), deaths related to fires caused by cigarettes (64 deaths), and non-smokers exposed to environmental tobacco smoke (4560 deaths).[26]

DISCUSSION

California has one of the most comprehensive tobacco control programmes in the nation, and the prevalence of smoking has been declining over time. Nonetheless, the health effects

Table 2 Cost of smoking by type of cost and sex, California, 1999

Type of cost and sex	Amount ('000s)	Distribution (%)	Per resident	Per smoker
Total	$15759779	100.0	$475	$3331
Direct cost	$8564623	54.3	$258	$1810
Hospital	$4016568	25.5	$121	$849
Ambulatory*	$2060234	13.1	$62	$435
Nursing home care	$1267232	8.0	$38	$268
Prescriptions	$1133432	7.2	$34	$240
Home health	$87157	0.6	$3	$18
Indirect lost productivity	$7195156	45.7	$217	$1521
Illness	$1512210	9.6	$46	$320
Premature death†	$5682946	36.1	$171	$1201
Men, Total	$9418889	100.0	$568	$3409
Direct cost	$4243211	45.1	$256	$1536
Hospital	$2130101	22.6	$128	$771
Ambulatory*	$1076995	11.4	$65	$390
Nursing home care	$472147	5.0	$28	$171
Prescriptions	$538307	5.7	$32	$195
Home health	$25661	0.3	$2	$9
Indirect lost productivity	$5175678	54.9	$312	$1873
Illness	$762098	8.1	$46	$276
Premature death†	$4413579	46.9	$266	$1598
Women, total	$6340890	100.0	$383	$3221
Direct cost	$4321412	68.2	$261	$2195
Hospital	$1886467	29.8	$114	$958
Ambulatory*	$983239	15.5	$59	$499
Nursing home care	$795085	12.5	$48	$404
Prescriptions	$595125	9.4	$36	$302
Home health	$61496	1.0	$4	$31
Indirect lost productivity	$2019478	31.8	$122	$1026
Illness	$750111	11.8	$45	$381
Premature death†	$1269367	20.0	$77	$645

Numbers may not add to total due to rounding.
*Includes physician and other professional services.
†Discounted at 3%.

Table 3 Smoking cost studies by type of study, California

Study	Study year	Cost (billions)		
		Direct	Indirect	Total
Kaplan and Wright[28]	1985	$4.8	$2.3	$7.1
US DHHS[29]	1985	NA	NA	$5.8
California Dept of Health Services[30]	1988	NA	NA	$5.9
Rice and Max[31]	1989	$2.4	$5.2*	$7.6
Max and Rice[32]	1993	$3.6	$6.3*	$10
V Miller *et al*[34]	1993	$7.1	NA	NA
L. Miller *et al*[16]	1993	$8.7	NA	NA
CDC[33]	1998	$7.1	NA	NA
Current study	1999	$8.6	$7.2†	$15.8

*Discounted at 4%.
†Discounted at 3%.
CDC, Centers for Disease Control and Prevention; DHSS, Department of Health and Human Services; NA, not available

of smoking cost Californians $15.8 billion in 1999. These estimates are conservative for several reasons. We did not take into account costs due to passive smoking, fires caused by cigarettes, non-health sector costs such as transportation to providers, and costs of smoking cessation programmes and other interventions to control smoking. We used the human capital approach in this study rather than contingent valuation,[27] which would yield much higher estimates for values of life.

We used average earnings in our estimates of lost productivity. We acknowledge that smokers tend to have lower than average earnings, but earnings data are not available for California smokers. Had these data been available, our estimates of indirect costs would likely have been slightly lower.

Our estimates of the cost of smoking in California are not the first; table 3 summarises the previous cost estimates made for the state. Studies that included both direct and indirect costs reported totals ranging from $5.8 billion for 1985 to $10 billion for 1993.[28–32] Our estimates of total costs for 1999 amount to $15.8 billion. Our estimate of direct smoking costs amounted to $8.7 billion which is almost three times the estimate made for 1989[31] and twice that made for 1993.[32] These differences result from the use of different methodology and data sources. The first five studies estimate SAFs using the epidemiological approach for attributable risk. Relative risks for mortality or for healthcare utilisation were used as a proxy for the relative risk of health expenditures. The SAFs in the current study were estimated using models which directly related smoking to health expenditures while controlling for other confounding factors, thus estimating the SAFs directly.

The three other recent studies also used econometric models and produced higher direct cost estimates than the earlier studies. The Centers for Disease Control and Prevention (CDC) study[33] estimated a direct cost of $7.1 billion for 1998, a 21% difference from ours. Part of the difference can be attributed to the annual cost increase; the remainder is the difference in methodology. The CDC estimates were based on the published SAF estimates by V Miller and colleagues,[34] in which health expenditures were modelled with a reduced form model. Our study was based on a causal relationship framework developed by L Miller and colleagues,[16] which we believe yields more accurate estimates. The V Miller and L Miller models are compared in detail elsewhere.[35]

Different from L Miller,[16] the current study used more recent data sources. Also, we included only the ''biological effect'' in the calculation of SAFs while Miller included both the ''biological t'' and the ''mixed effect''. Because 80–90% of the total effect came from the biological component and the biological SAFs were more stable, this refinement improves the methodology. Despite the fact that personal medical care expenditures have increased since 1993, the lower SAFs resulted in our direct cost estimate for 1998 being $8.6 billion compared to $8.7 billion for 1993 by L Miller.[16]

Californians not only have lower smoking prevalence than most other states, but current California smokers have lower per capita consumption. This might cause our modelling approach to overestimate costs. However, the needed data on smoking intensity over time were not available to permit a model of the impact of this effect on health expenditures.

Between 1989 and 1999, the first decade of the California Tobacco Control Program, adult smoking prevalence decreased 24% in California compared to 17% in the USA as a whole.[36] It is clear from this and our previous work that there has not been a dramatic reduction in smoking-related costs in the state over this time period. Without the tobacco control programme, smoking related costs would have been even higher. Thus, even a state such as California, with a tobacco control programme that is considered among the strongest in the nation, must remain vigilant in its efforts to maintain hard won reductions in smoking prevalence, and cannot expect cost savings to show up for a number of years.

The question has been raised as to whether smokers are paying for their smoking habits. A related question is whether cigarette taxes are at the appropriate level. From an economic perspective, the tax should be set to cover the external costs of smoking—that is, the costs imposed by smokers on others. While we did not estimate the proportion of costs that are internal versus external, Gruber[37] summarised other studies which found that external health care costs alone probably range from $1.55 to $1.85 per pack. In addition, sizeable external losses in workplace productivity have not been estimated.[37] We found that smoking related direct costs per pack of cigarettes were $6.16, and total direct and indirect costs totalled $11.34 per pack. Current tax proposals in California are to raise the tax per pack of

What this paper adds

Much of the research on smoking related costs has been conducted at the national level or did not use the most current accepted methodology for cost estimation. Few studies have developed current estimates at the state or local level; yet this is where many tobacco control activities occur.

This study shows the feasibility of applying the econometric approaches used at the national level to obtain good state estimates. The modelling approach is described and the most current estimates for California are presented.

cigarettes by up to $1.50, which would seem easily justified by the likely magnitude of the external costs. However, it must also be noted that from an equity perspective, if part of the tobacco tax increase is to be passed on to smokers, the revenues raised should be used to help them quit smoking and obtain health care for smoking related illnesses they may already have.

The public health impact of cigarette smoking in California and in the USA is enormous in terms of the large number of preventable illnesses, premature deaths, and high health care costs and productivity losses. Policymakers must continue to push legislation and ordinances that encourage people to quit or to never take up smoking. The approach presented here is useful for other states, nations, and jurisdictions interested in estimating the costs of smoking.

To view the Methods section, visit the Tobacco Control website–http://www.tobaccocontrol.com/supplemental.

Authors' affiliations

W Max, D P Rice, H-Y Sung, Institute for Health & Aging, University of California, San Francisco, San Francisco, California, USA
X Zhang, Institute of Social Development and Public Policy, Beijing Normal University, Beijing, China
L Miller, School of Social Welfare, University of California, Berkeley, Berkeley, California, USA

REFERENCES

1 **McGinnis JM**, Foege WH. Actual causes of death in the United States. *JAMA* 1993;**270**:2207–12.
2 **Fellows JL**, Trosclair MS, Adams EK, *et al*. Annual smoking-attributable mortality, years of potential life lost, and economic costs—United States, 1995–999. *MMWR Morb Mortal Wkly Rep* 2002;**51**:300–3.
3 **US Department of Health, Education, and Welfare**. *Smoking and health. Report of the Advisory Committee to the Surgeon General of the Public Health Service*. Washington, DC: Public Health Service, 1964, (PHS Publication No.1103.).
4 **US Department of Health and Human Services**. *The health consequences of smoking: cancer. A report of the Surgeon General, 1982*. Bethesda, Maryland: Public Health Service, Office on Smoking and Health, 1982 (DHHS Publication No (PHS) 82-50179.).
5 **US Department of Health and Human Services**. *The health consequences of smoking: cardiovascular disease. A report of the Surgeon General, 1983*. Rockville, Maryland: Public Health Service, Office on Smoking and Health, 1983, (DHHS Publication No (PHS) 84-50204.).
6 **US Department of Health and Human Services**. *The health consequences of smoking: chronic obstructive lung disease. A report of the Surgeon General, 1984*. Rockville, Maryland: Public Health Service, Office on Smoking and Health, 1984, (DHHS Publication No (PHS) 84-50205.).
7 **US Department of Health and Human Services**. *Reducing the health consequences of smoking: 25 years of progress. A report of the Surgeon General, 1989*. Rockville, Maryland: Public Health Service, Centers for Disease Control, Office on Smoking and Health, 1989, (DHHS Publication No (CDC) 89-8411.).
8 **US Department of Health and Human Services**. *Preventing tobacco use among young people. A report of the Surgeon General, 1994*. Atlanta, Georgia: Public Health Service, Centers for Disease Control and Prevention, Office on Smoking and Health, 1994, (US Government Printing Office Publication No S/N 017-001-00491-0.).
9 **US Department of Health and Human Services**. *Tobacco use among U.S. racial/ethnic minority groups: African Americans, American Indians and Alaska Natives, Asian Americans and Pacific Islanders, Hispanics. A report of the Surgeon General, 1998*. Atlanta, Georgia: Centers for Disease Control and Prevention, Office on Smoking and Health, 1998, (US Government Printing Office Publication No S/N 017-001-00527-4.).
10 **US Department of Health and Human Services**. *Women and smoking: A report of the Surgeon General*. Atlanta, Georgia: US Department of Health and Human Services, Centers for Disease Control and Prevention, 2001.
11 **Centers for Disease Control**, Prevention (CDC). State-specific prevalence of current cigarette smoking among adults—United States, 2002. *MMWR Morb Mortal Wkly Rep* 2004;**52**:1277–80.
12 **Tobacco Education and Research Oversight Committee**. *Toward a tobacco free California, 2003–2005: the myth of victory*. Sacramento, California: California Department of Health Services, January, 2003.
13 **Max W**, Rice DP, Zhang X, *et al*. *The cost of smoking in California, 1999*. Sacramento: California Department of Health Services, 2002, Available at http://repositories.cdlib.org/ctcre/tcpmus/CA2002.
14 **Bartlett JC**, Miller LS, Rice DP, *et al*. Medical expenditures attributable to cigarette smoking—United States, 1993. *MMWR Morb Mortal Wkly Rep* 1994;**43**:469–72.
15 **Miller LS**, Zhang X, Rice DP, *et al*. State estimates of total medical expenditures attributable to cigarette smoking, 1993. *Public Health Reports* 1998;**113**:447–58.
16 **Miller LS**, Zhang X, Novotny T, *et al*. State estimates of Medicaid expenditures attributable to cigarette smoking, fiscal year 1993. *Public Health Reports* 1998;**113**:140–1.
17 **Zhang X**, Miller LS, Max W, *et al*. Cost of smoking to the Medicare program, 1993. *Health Care Financing Review* 1999;**20**(4):179–96.
18 **Zhang X**. Cigarette smoking and nursing home utilization in the United States: An estimate of 1993 national and state nursing home expenditures attributable to cigarette smoking. Berkeley: PhD Dissertation, University of California, 1999.
19 **Martin AB**, Whittle LS, Levit KR. Trends in state health care expenditures and funding: 1990–1998. *Health Care Financing Review* 2001;**22**(4):111–40.
20 **Lilienfeld AM**, Lilienfeld DE. *Foundations of epidemiology*. Oxford: Oxford University Press, 1980.
21 **US Bureau of the Census**. In: *Statistical abstract of the United States: 2000*, 120th ed. Washington DC: US Government Printing Office, 2000.
22 **Douglass JB**, Kenney GM, Miller TR. Which estimates of household production are best? *Journal of Forensic Economics* 1990;**4**:25–45.
23 **California Department of Health Services (CDHS)**. *California death statistical master file—1999*. Sacramento: CDHS, Center for Health Statistics, Office of Health Information and Research, Vital Statistics Section, 1999.
24 **California Department of Health Services (CDHS)**. *Abridged life table for total population, 1999*. Sacramento: CDHS, Center for Health Statistics, Office of Health Information and Research, Vital Statistics Section, 1999.
25 **Max W**, Rice DP, Sung H-Y, *et al*. *Valuing human life: estimating the present value of lifetime earnings, 2000*. Available at: http://repositories.cdlib.org/ctcre/esarm/PVLE2000.
26 **National Cancer Institute (NCI)**. *Health effects of exposure to environmental tobacco smoke: the report of the California environmental protection agency*, Smoking and Tobacco Control Monograph no.10. Bethesda, Maryland: US Department of Health and Human Services, National Institutes of Health, National Cancer Institute, 1999, (NIH Publication No 99–4645.).
27 **Institute of Medicine**. *Hidden costs, value lost: uninsurance in America*. Washington DC: The National Academies Press, 2003:35.
28 **Kaplan GA**, Wright WE. *Health and economic impact of smoking, California, 1985*. Sacramento: California Department of Health Services, 1988.
29 **US Department of Health and Human Services**. *Smoking and health, a national status report: A report to Congress*, 2nd ed.revised February 1990. Rockville, Maryland: US Public Health Service, 1990, (DHHS Publication No (CDC) 87–8396.).
30 **California Department of Health Services (CDHS)**. *Health and economic impact of smoking: California, 1988*, Technical Report No.5. Sacramento: California Chronic and Sentinel Diseases Surveillance Program, 1992.
31 **Rice DP**, Max W. *The cost of smoking in CA, 1989*. Sacramento: California Department of Health Services, 1992.
32 **Max W**, Rice DP. The cost of smoking in California, 1993. *Tobacco Control Summer* 1995;**4**(suppl 1):S39–46.
33 **Centers for Disease Control**, Prevention (CDC). *Tobacco control state highlights 2002: impact and opportunity*. Atlanta, Georgia: Department of Health and Human Services, CDC, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2002, Available at:http://www.cdc.gov/tobacco/statehi/statehi_2002.htm.
34 **Miller VP**, Ernst C, Collin F. Smoking-attributable medical care costs in the USA. *Soc Sci Med* 1999;**48**:375–91.
35 **Warner KE**, Hodgson TA, Carroll CE. Medical costs of smoking in the United States: estimates, their validity, and their implications. *Tobacco Control* 1999;**8**:290–300.
36 **Gilpin EA**, Emery SL, Farkas AJ, *et al*. *The California tobacco control program: a decade of progress, results from the California tobacco surveys, 1990–1999*. La Jolla: University of California, San Diego, 2001.
37 **Gruber J**. The economics of tobacco regulation. *Health Affairs* 2002;**21**(2):146–62.

Web-Only Methods Section

The methods described in this section summarise the complex econometric approach that was used for estimating the cost of smoking in California. Further details are contained in a comprehensive report that includes estimates for the 58 counties of the state of California.[13] This study used a prevalence based approach, in which the annual economic burden of smoking was estimated for all smoking related illness and deaths that occurred in 1999 regardless of when a person first became ill. The burden of smoking consists of three components: direct cost, indirect cost of lost productivity from smoking related illness, and indirect cost of premature deaths caused by smoking related disease. The estimation of these three components relied on a common conceptual approach. In each case, a smoking attributable fraction (SAF) was estimated and applied to the total measure of interest. For example, the SAF for hospitalisation expenditures represents the proportion of hospitalisation expenditures that are attributable to smoking. This SAF was multiplied by the total hospitalisation expenditures to obtain smoking attributable hospital expenditures.

Direct costs

The direct costs of smoking in California are the health care expenditures for treatment of smoking related disease. Five types of health care services were included: hospitalisations, ambulatory care, nursing home care, prescription drugs, and home health care. Separate SAF models were developed for each type of heath care services for males and for females aged 18 years and older

with the exception of the nursing home model, which was limited to those aged 55 and older because nearly all expenditures for nursing home care are limited to this older age group. These models were estimated using national data; California specific values of all independent variables were then used in the models to derive the California specific SAFs.

The national SAF models for hospitalisations, ambulatory care, prescription drugs, and home health care were based on the latest econometric approach developed by the authors[14–17] and were estimated by using the 1999 Aged National Medical Expenditure Survey (NMES). These models consist of multiple equations describing the effect of smoking history S (current, former, and never smokers) on the past history of five major smoking related diseases D (cancer, emphysema, arteriosclerosis, heart attack, and stroke), on self reported poor health status H, on the probability of having positive health care expenditures X, and on the magnitude of expenditures given that expenditures are positive. Demographic and socioeconomic status Y (age, race/ethnicity, geographic region, marital status, education, health insurance coverage, and family income) and other risk behaviours R (obesity and seatbelt use) were controlled in the model. The structural forms of these equations are:

$$D^* = f_1 (S, Y, R) \quad (1)$$

$$H^* = f_2 (S, Y, R, D^* | D) \quad (2)$$

$$\text{Prob}(X>0) = f_3 (S, Y, R, H^* | H) \quad (3)$$

$$\text{Log}(X|X>0) = f_4 (S, Y, R, H^* | H) \quad (4)$$

D is a binary variable that equals one if the respondent reported having one of the five major tobacco related diseases and zero otherwise. D* is an unobservable variable for the propensity for having major tobacco related diseases and was estimated as a probit model. H is self reported health status categorised as excellent, good, fair, or poor. H* is an unobservable variable for the propensity of having poor health and was estimated as an ordered probit model. $D^*|D$ denotes the expected propensity for having tobacco related disease conditional on self reported disease history. Likewise, $H^*|H$ denotes the expected propensity for having poor health conditional on self reported health status. Equation 3 was estimated as a probit model. Equation 4 is the logarithm of the magnitude of expenditures for those individuals with expenditures and was estimated using ordinary least squares.

The estimated coefficients of the national models were applied to 1999 California Tobacco Survey data to calculate predicted expenditures for each California male and female based on the actual values of all the independent variables. Another set of predicted expenditures was calculated for “hypothetical smokers” (current and former) who were identical to smokers in every way except that they were assumed to be never smokers. The difference between these two sets of predicted expenditures is the excess cost of smoking. The ratio of this difference to the aggregate predicted expenditures is the SAF.

Smokers have higher health expenditures because they are more likely to have smoking related diseases and poorer health (the “biological effect”). However, there is also a “mixed effect” that can increase or decrease expenditures for

reasons not directly related to health status. For example, pregnant women do not generally describe themselves as being in poor health; yet pregnant smokers and their newborns often have higher medical expenses than their non-smoking counterparts. On the other hand, smokers might use fewer healthcare services than comparably healthy non-smokers due to their risk taking personalities and a resulting lower preference for seeking medical care. Because the mixed effects pathway was not causally related to tobacco use, and because 80–90% of the total effect results from the biological effect, mixed effects were not included here in the calculation of predicted excess costs of smoking and SAF. While the smoking variable remains in the model, for the final estimation it was replaced by mean current smoking prevalence, rather than 0 or 1.

The SAF for nursing home care was estimated using a conceptual model developed by Zhang.[18] According to this model, patients may be admitted to a nursing because they suffer from smoking related illness (the disability effect), or they may be forced to move to a nursing home when their caregiver dies from a smoking related illness and there is no one to care for them (the mortality effect). These effects combine to cause an increase in nursing home expenditures that is attributed to smoking. This model was estimated using the 1982–84 and 1987 National Health and Nutrition Examination Survey (NHANES) I epidemiologic followup study.

Smoking attributable expenditures in California were estimated for males and females, and for each of the five types of health care services, by multiplying the appropriate SAF by the corresponding state health care expenditure published by

the Health Care Financing Administration (HCFA) for people aged 18 and older.[19] Expenditures were inflated to 1999 dollars using the appropriate component of the Consumer Price Index.

Indirect costs of lost productivity due to illness

Smokers with smoking related illnesses miss days of work and are unable to perform their usual activities. Two indicators of morbidity costs were considered here: smoking attributable work loss days and bed disability days. These were determined as the product of the SAF and the total number of days lost. We adapted the standard epidemiological formula to calculate SAFs for work loss days and bed disability days[20]:

$$SAF = \frac{[(p_n + p_c(RR_c) + p_f(RR_f)] - 1}{[(p_n + p_c(RR_c) + p_f(RR_f)]} \quad (5)$$

where p_n, p_c, and p_f denote the percentage of never, current, and formers smokers; RR_c (RR_f) denotes the relative risk of the outcome measure of interest for current (former) smokers relative to never smokers. Relative risk for days lost was estimated using an econometric approach. First, work loss days or bed disability days were specified as a function of smoking status controlling for geographic region, demographic and socioeconomic variables and other risk behaviours and was estimated using a Tobit model. Work loss days were estimated separately for males and females 18 and older who were in the labour market using data from the 1999 National Health Interview Survey (NHIS). The model for bed disability days was estimated for females aged 18 and older who were not in the labour force but who were housekeeping using the 1999 NHIS data. The small sample size for males precluded estimation of smoking attributable bed disability

days for them. Finally, the relative risk for current (or former) smokers was calculated as the ratio of predicted days for current (former) smokers to predicted days for "hypothetical current (former) smokers" with all the same characteristics of current (former) smokers except that they were assumed to be never smokers. The relative risk estimates were then used in equation 5 along with smoking prevalence rates estimated from the 1999 California Tobacco Survey data to determine the California specific SAFs.

Total days lost in California were extrapolated from the 1999 NHIS data, assuming that the work loss days and bed disability days in California were 11.96% of the US total since California represents 11.96% of the US total population aged 18 and older.[21] The SAF for days lost was applied to the total number of days lost to obtain smoking attributable days of lost productivity. For those in the labour market, work loss days were valued using California specific mean daily earnings plus an imputed value for household services by age and sex. For those not in the labour force, bed disability days were valued using a California specific mean daily imputed value for household services by age and sex. Labour market earnings included an adjustment for fringe benefits. The imputed value for household production was calculated by applying the mean wage rate for performance of tasks similar to those performed by housekeepers using the methodology developed by Douglass *et al*.[22]

Indirect costs of lost productivity due to premature death

We used the human capital approach to measure the value of lost productivity from lives lost due to smoking attributable diseases. The cost to society of

smoking attributable premature death was calculated as the product of smoking attributable deaths and the present value of lifetime earnings (PVLE) for each person. We also estimated years of potential life lost due to smoking caused deaths.

The number of smoking attributable deaths was estimated by multiplying the SAFs by total deaths for each underlying cause of death reported as being causally linked to smoking in the 25th anniversary report of the US Surgeon General.[7] The SAF was determined for each age group and sex according to the epidemiological formula described above in equation 5. The relative risk of death by disease used was published by the Surgeon General.[7] Smoking prevalence rates were estimated using the 1999 California Tobacco Survey. Deaths for each smoking related diagnosis by sex and age (in five year category) were obtained from the 1999 California Death Statistical/Master file.[23] Only deaths for newborns and adults aged 35 and older were included.

The number of years lost from smoking caused death was estimated by sex and five year age group as the product of the number of smoking attributable deaths and the average number of years of life expectancy remaining at the age of death. Average remaining years of life for Californians was obtained from the California Department of Health Services.[24]

PVLE per person was estimated by five year age groups and sex using a computer program maintained at the University of California, San Francisco.[25] It takes into account life expectancy for different sex and age groups, varying rates of labour force participation or housekeeping, changing pattern of earnings at

successive ages, an imputed value for housekeeping services, and a 3% discount rate to convert a stream of earnings into its current worth. To predict the future pattern of earnings, imputed value for household services, and labour force and housekeeping participation rates, it is assumed that people will be working and productive during their lifetimes in accordance with the current pattern of earnings and work experience for their sex and age groups. For this calculation, the proportions of the population participating in the labour force and housekeeping were estimated from the 1999 NHIS data.