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Gauging the Effect of U.S. Tobacco Control Policies From 1965 Through 2014 Using SimSmoke

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Abstract

Introduction—The year 2014 marked the 50th Anniversary of the first Surgeon General's Report. This paper estimates the effect of tobacco control policies in the U.S. after the 1964 Report using the SimSmoke tobacco control simulation model.

Methods—SimSmoke uses National Health Interview Survey data from 1965 through 2012 on smoking prevalence, initiation, and -cessation rates, and incorporates policies implemented since 1965. The model projects smoking prevalence and smoking-attributable deaths (SADs) from 1965 through 2065 and is validated against National Health Interview Survey data. Counterfactual scenarios with policies constant since 1965 and with individual policies are estimated. Analysis was conducted in February 2014.

Results—SimSmoke generally validated well over the time period 1965 through 2012. As a result of all policies, smoking prevalence is estimated to have fallen by almost 55% by 2014 with a total of 2 million SADs s averted from 1965 through 2014, increasing to 20.1 million SADs by 2065. The Fairness Doctrine is estimated to have reduced adult smoking prevalence by about 24% by 2014 and averted 10.4 million SADs by 2065, while price increases reduced smoking prevalence by 24% by 2014 and averted 7.3 million SADs by 2065. Smoke-free air laws, cessation treatment, and tobacco control spending individually reduced smoking rates by 3%–5.5% by 2014.

Conclusions—By 2014, SimSmoke predicts a 53% reduction in smoking rates and almost 2 million SADs averted due to polices implemented since the 1964 Surgeon General's Report, with most of the health benefit still to occur in future years.

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Introduction

Following the Surgeon General's Report[1] in 1964, legislation banned cigarette advertising and publicized the dangers of smoking. Smoke-free air efforts began in the 1970s.[2] Since 1989, states implemented smoke-free air laws, media campaigns, cessation programs, and cigarette tax increases.[2] Warner et al.[3] found large reductions in cigarette consumption, but did not consider premature deaths. Using a cohort analysis, Holford and colleagues[4] estimated 8 million smoking-attributable deaths (SADs) averted as a result of these efforts, but did not consider the effect of individual policies.

This study estimates the effect of tobacco control policies implemented in the U.S. since 1964 using the SimSmoke tobacco control policy model. The model is validated over a 50-year period (1965–2012). This study then estimates the effects of policies on smoking prevalence and the number of projected SADs averted through 2065.

Methods

SimSmoke begins with the number of current, former, and never smokers by age and gender in 1965. Following a discrete first-order Markov process, current and former smokers evolve through initiation, cessation, and relapse. SADs are estimated for current smokers as the excess mortality risk (defined as the current minus never smoker mortality rate) multiplied by the number of smokers, and similarly for former smokers (distinguished by years quit[5]). Data used in the model are presented in Table 1. Smoking prevalence and initiation and cessation rates are from the National Health Interview Survey (NHIS),[6] with relapse distinguished by years quit.[7,8]

SimSmoke incorporates the effects of changes in policies from 1965 through 2014. Policy effects are modeled through reductions in smoking prevalence in the first year, sustained or increased in future years through initiation, and cessation rates. Table 2 presents effect sizes, which were previously developed except for advertising restrictions/Fairness Doctrine (AR/FD). Based on Lewitt et al.,[9] Warner,[10,11] a 39% reduction in initiation rates and 8% increase in cessation rates are attributed to AR/FD.

The FD required anti-smoking messages in 1967 and cigarette advertising was banned on radio in 1970 and TV in 1971.[2] Cigarette retail prices[12] adjusted for inflation show a 30% increase between 1965 and 1994, but doubled between 1994 and 2014.[2] By 2014, 65.1% of worksites, 77.4% of restaurants, and 65.2% of bars were smoke free,[2] with initial compliance at 20% increasing to 80% by 2000. Beginning with California in 1989,[13] tobacco control campaigns increased from a low level in 1989 to mid level by 2003. Health warnings[2,14] were first placed on cigarette packs in 1966 with changes in 1970 and 1985, but are still weak. Cessation treatment policy includes pharmacotherapy availability, financial coverage, and quit lines.[15,16] Nicotine gum became available in 1988, the nicotine patch in 1993 and without prescription in 1997, Bupropion in 1998, and Varencline in 2002. Starting in 1995, treatments were provided in some healthcare facilities and in some cases financially subsidized. A national quit line was implemented in stages beginning in 2000. Among youth access policies, enforcement is considered low from 1995 to 1999 and

medium since 2000,[2] vending machine bans increased to 75% by 2000, and all self-service was banned by 2010.

SimSmoke was calibrated against NHIS smoking prevalence through 1983, and validated through 2012 by year and age group. To estimate the effect of policies implemented between 1965 and 2014, policies are first set to their 1965 levels to obtain the counterfactual (no policies implemented) smoking prevalence. The percentage difference between the smoking prevalence with policies and the counterfactual yields the net effect of policies. Their health impact is derived as the difference in SADs with policies and under the counterfactual. The analysis was conducted in February 2014.

Results

SimSmoke (Table 3) predicts very similar reductions in adult smoking prevalence to NHIS rates in 2012 (61% vs 61% for men and 54% vs 53% for women). By 2012, SimSmoke obtains very similar estimates to NHIS estimates by age group, within the NHIS CIs for all age groups except women aged 45–64 and ≥65 years. However, SimSmoke overestimates smoking prevalence for men and for women aged ≥45 years between 1983 and 1993.

The predicted counterfactual smoking prevalence (Table 4) with no policy change is 43% for men and 33% for women in 2014 compared with 20% for men and 16% for women with actual policies, representing a 53% relative reduction. By 2014, SimSmoke projects an estimated 2 million SADs averted as a result of all policies. A 65% reduction in smoking prevalence and 20.1 million SADs averted are projected by 2065.

A 25% reduction in smoking prevalence is projected resulting from AR/FD, resulting in a 900,000 fewer SADs by 2014 increasing to 10.4 million by 2065. Price increases result in a 23% prevalence reduction by 2014 and 7.3 million SADs averted by 2065. With smoke-free air laws mostly implemented since 1990,[2] SimSmoke estimates a 5.5% prevalence reduction by 2014, averting 2 million SADs by 2065. Smaller effects of smoking prevalence are estimated for tobacco control spending and cessation treatment policies by 2014, but the effects of cessation treatment policies grow more rapidly over time. The current weak health warnings show little effect by 2014. With youth access policies mostly implemented since the mid-1990s,[2] their predicted effect on prevalence is small (2%) by 2014 because they only affect youth, but 330,000 SADs are averted by 2065.

Discussion

As a result of all policies since 1964, smoking prevalence is estimated to have fallen by almost 55%, averting 2 million SADs by 2014 and 20.1 million by 2065. The largest effects are from the AR/FD implemented soon after 1964 and price increases mostly since 1994.

Although this analysis considers policies implemented after 1965, publicity surrounding the Surgeon General's Report and research on the harms of smoking were already disseminated. Male rates had reached as high as 65% in the fifties and female rates near 50% prior to 1964.[2] Holford and colleagues[4] and Warner[10] projected that male ever smoker prevalence would have been at least 70% and female rates would have been around 60%. Rather than

the smoking prevalence starting at 52% for men and 35% for women and slowly declining, the SimSmoke counterfactual was re-estimated with male and female smoking prevalence held constant at 60% and 45%, respectively. In this scenario, the number of SADs averted as a result of tobacco control increased to more than 8 million by 2014, similar to the estimate by Holford et al.[4]

Similar to previous SimSmoke models,[17–27] this model validated well for smoking prevalence, with the notable exception of male prevalence in the 1980s and early 1990s. During the 1980s, three Surgeon General's Reports were published and 47% of workers were already covered by smoking restrictions by 1993.[28] The underlying change in social norms and industry behavior are not incorporated in SimSmoke projections, and may explain the smoking rates being lower than model predictions in the 1980s and early 1990s.

The strength of evidence for each policy varies.[29,30] In other analyses,[18,20] sensitivity analysis was conducted with effect sizes varying by 25% for taxes; by 50% for smoke-free air and tobacco control campaigns; and by 75% for cessation treatment, health warnings, and youth access policies. The relative risks associated with smoking are based primarily on the Cancer Prevention Study (CPS)-I and CPS-II. Reductions in quantity smoked were not considered.[6] Nevertheless, recent studies[31,32] indicate higher smoking relative risks than the CPS-I and CPS-II.

SimSmoke predicts substantial reductions in smoking prevalence reductions SADs from past policies, indicating that continued tax increases, extending comprehensive smoke-free air laws, strong health warnings, and broader cessation treatment programs can yield additional public health gains.

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Table 1

Data Used in *U.S. SimSmoke*

Variable	Current source	Current specifications
I. Population model		
A. Population	1965–2065 Census and Census Projections	Breakdowns by single age and gender
B. Mortality rates	1965–2065 Multiple Cause-of-Death File	Breakdowns by single age, gender
II. Smoking model-initialized in 1965, with future changes fur to changes in initiation and cessation rates as reflected by policies through policy modules		
A. Baseline smoking rates for current and ex-smokers	1965 National Health Interview Survey (NHIS) for age 10+	100+ cigarettes lifetime including current every day and some day current smokers, and former smokers by years quit(<1, 1–2, 3–5, 6–10, 11- 14, 15+ years) by single age and gender
B. Initiation rates	1965–2012 NHIS for age 10 and above	Breakdowns by single age and gender
C. First year cessation rates	1965–2012 NHIS for ages 16 and above	Breakdowns by single age and gender
D. Relapse rates	Previous studies[7,8]	Breakdowns by age group and gender
E. Excess death risks of smokers and ex-smokers	1965–2065 death rates by current, former and never smokers as developed using and Cancer Prevention Study I and II by Holford et al.[4]	Breakdowns by age, gender and smoking status
III. Policy Modules-levels from 1965–2014		
A. Price and Taxes	Prices and taxes from Tobacco Institute,[12] adjusted for inflation using the consumer price index from the Bureau of Labor Statistics[33]	Prices averaged over states with weights based on tobacco sales and include generic cigarettes and CPI for 1965–2014
B. Smoke-free air laws	Laws from State Tobacco Activities Tracking and Evaluation (STATE) System[34] and compliance from selected references[35–37]	State (weighted by population) smoke-free air laws for worksites, restaurant, bars and other public places each distinguished by stringency (compete, limited to ventilated areas and in particular areas) and enforcement based on compliance
C. Fairness Doctrine and Advertising Restrictions	U.S. DHHS[2] and Warner[10,11]	Indicator of strength beginning at year of adoption or Fairness Doctrine and advertising restrictions
D. Tobacco control campaigns (mostly media campaigns)	Expenditures from State Tobacco Activities Tracking and Evaluation (STATE) System[34]	Tobacco control expenditures per capita by state used to create indicator (high, medium and low)
E. Health Warnings	U.S. DHHS[2]	Indicator of Strength (high, medium and low)
F. Cessation Treatment Programs	State Tobacco Activities Tracking and Evaluation (STATE) System[34] and USDHHS[2] and Levy et al.[15,16]	Indicators of when pharmacotherapies became available, cessation treatment locations and quitlines
G. Youth access	Laws from State Tobacco Activities Tracking and Evaluation (STATE) System[34] and USDHHS[38] and compliance from SAMHSA [39]	Synar data on compliance checks, self-service and vending machine bans based on state weighted measure of percent applicable

Table 2

Policy Inputs and Effect Sizes for *NHIS SimSmoke*

Policy	Description	Potential percentage effect[a]
	Cigarette taxes[40]	
Cigarette price	The state level average price for a pack of cigarettes (including branded and generic), including state and federal excise taxes.	For each 10% price increase: 6% reduction ages 15–17, 4% reduction ages 18–24, 2% reduction ages 25–34, & 1% reduction ages 35 &above
	Smoke-free air laws[41]	
Worksite ban, well- enforced	Smoking banned in all indoor worksites in all areas	6% reduction
Worksite restrictions, weak	Smoking in restricted areas only	2% reduction
Restaurant and bar ban, well enforced	Ban in all indoor restaurants in all areas	2% reduction
Restaurant ban, weak	Smoking in restricted areas only	1% reduction
Other public places bans	Ban in 3 of 4 (retail stores, arenas, public transportation and elevators)	1% reduction
Enforcement and publicity	Enforcement based on compliance rates[38] and publicity based on the level of tobacco control campaigns (see below)	Effects reduced by as much as 50% if no compliance or publicity
	Fairness Doctrine and advertising restrictions[9–11]	
Existence of Fairness Doctrine	Airing of anti-smoking messages on radio and television from July 1, 1967, to January 1, 1971, and banning of cigarette advertising on radio in 1970 and television in 1971	39% reduction in initiation rates, 8% increase in cessation rates
	Tobacco control campaigns[13]	
Well-funded campaign	Campaign expenditures meeting 90% of the pre-2009 CDC minimum recommended	6.5% reduction
Moderately funded campaign	Campaign expenditures meeting 50% of the pre-2009 CDC minimum recommended	3.6% reduction
Low funded campaign	Campaign expenditures meeting < 25% of the pre-2009 CDC minimum recommended	1.2% reduction
	Health warnings[30]	
Weak health warnings	Non-graphic warning covers less than one-third of the package.	1% reduction in prevalence and 2% increase in cessation only
	Cessation treatment programs[15,16]	
Availability of NRT, Bupropion and Varenicline	If NRT is provided by pharmacy w/ Rx =1 and =2 If NRT is provided by general store or pharmacy (no Rx required). If Bupropion and Varenicline are provided with Rx =1.	1% reduction if score of 3[b]
Provision of treatments	Types of facilities distinguished, specified as primary care facilities, hospitals, offices of health professionals. community and other, and financial coverage of pharmacotherapies by Medicaid and private insurers	2.25% reduction if indicator =2 for all facilities and program is well publicized[b]
Quit line	Operating active quit line	0.5% reduction[b]
Comprehensive cessation treatment	Proactive quit line with NRT, complete treatment coverage through insurance	~ 3% reduction in prevalence, and 20% increase in cessation[b]
	Youth access restrictions[39]	

Policy	Description	Potential percentage effect[a]
High enforcement with vending machine and self- service bans	Non-compliance rates <5% among retailers, and with heavy publicity and community involvement	20% reduction for those ages 16–17 and 30% reduction for those age <16[c]
Medium enforcement	Non-compliance rates >5% and <15%, and with some publicity	10% reduction for those ages 16–17 and 15% reduction for those age <16[c]
Low enforcement	Non-compliance rates >15% in purchases, with little publicity	2.5% reduction for those ages 16–17 and 4% reduction for those age <16[c]

[a]The effect sizes are shown relative to the absence of any policy. Unless otherwise specified, the same percentage effect is applied as a percentage reduction in the prevalence in the initial year and as a percentage reduction in initiation rate and a percentage increase in the cessation rate in future years, and is applied to all ages and both genders.

[b]Applied to prevalence and first year quit rates only.

[c]Applied to initiation and prevalence only. NHIS, National Health Interview Survey; NRT, Nicotine Replacement Therapies.

Table 3

Validation of U.S. Smoking Prevalence: *SimSmoke* vs. NHIS Estimates, Male and Female, 1965–2012

2Age group	Smoking prevalence by year, % (CI)					Relative change[a] %		
Male								
SimSmoke	**1965**	**1983**	**1992**	**2003**	**2012**	**1965–1992**	**1992–2012**	**1965–2012**
18 years and over	52.1	39.7	33.3	25.4	20.2*	−36	−39	−61
18–24 years	53.8	36.3	31.3*	23.4	20.5*	−42	−35	−62
25–44 years	59.6	47.3	38.3	30.2	25.2*	−36	−34	−58
45–64 years	51.9	39	24.6	26.2	19.6*	−53	−20	−62
65 years and over	28.7	21.5	17.4*	12.2	10.3*	−39	−41	−64
NHIS								
18 years and over	52.0	35.1	28.6 (27.8,29.4)	24.0	20.5 (19.6,21.4)	−45	−28	−61
18–24 years	54.1	32.9	28.0 (25.5,31.5)	26.3	20.1 (17.1,23.1)	−48	−28	−63
25–44 years	59.4	39.7	32.8 (31.6,34.0)	28.4	25 (23.8,27.1)	−45	−23	−57
45–64 years	51.9	35.9	28.5 (27.1,30.1)	23.9	20.2 (18.8,21.6)	−45	−29	−61
65 years and over	28.5	22	16.1 (14.5,17.7)	10.1	10.6 (9.3,12.0)	−44	−34	−63
Female								
SimSmoke	**1965**	**1983**	**1992**	**2003**	**2012**	**1965–1992**	**1992–2012**	**1965–2012**
18 years and over	33.7	29.4	25.3*	19.8	15.9*	−25	−37	−53
18–24 years	37.8	26.7	22.8*	17	14.7*	−40	−36	−61
25–44 years	43.9	35.7	29.3*	23.2	19.0*	−33	−35	−57
45–64 years	32.0	32.3	29.1	22.6	17.4	−9	−40	−46
65 years and over	9.8	14.1	13.6	10.4	8.8	39	−35	−10
NHIS								
18 years and over	34.5	30.3	24.8 (23.9,25.3)	19.7	15.8 (15.1,16.5)	−28	−36	−54
18–24 years	38.1	35.5	24.9 (22.8,27.0)	21.5	14.0 (12.3,16.7)	−35	−42	−62
25–44 years	43.7	33.1	28.7 (27.7,29.9)	22.8	17.8 (16.6,19.0)	−34	−38	−59
45–64 years	32	31	26.1 (24.8,27.4)	20.2	18.9 (17.6,20.2)	−18	−28	−41

2Age group	Smoking prevalence by year, % (CI)					Relative change[a] %		
65 years and over	9.6	13.1	12.4 (11.3,13.5)	8.3	7.5 (6.6,8.5)	29	−40	−22

[a] Relative change computed was using the formula: (smoking rate in the latter year - smoking rate in the former year)/smoking rate in the former year.

* Indicates that the value of the *SimSmoke* prediction is within the 95% CI of the NHIS estimate NHIS, National Health Interview Survey

Table 4

SimSmoke Projections with Actual Policies and Counterfactuals (i.e., no policies changed since 1965), Male and Female, 1965–2065

	1965	1990	2014	2065	1965	1990	2014	2065	1965–2014	1965–2065
	Smoking prevalence, %				Number of smoking attributable deaths					
Male										
No policies[a]	52.1	46.5	43.0	40.2	237,768	316, 268	374,856	440,809	15,674,013	38,191,366
All policies[b]	52.1	34.8	19.3	14.4	237,768	302, 037	277,770	160,124	14,283,843	25,397,281
	Change relative to no policies,[c] %				Number of deaths averted compared to no policies[d]					
All policies[b]	-	−25.2	−55.1	−64.1	-	14,232	97,086	280,685	1,390,170	12,794,085
Price only	-	−5.9	−24.1	−31.2	-	2,198	28,988	132,532	353,286	4,684,920
Smoke free air only	-	−0.7	−5.4	−5.5	-	680	7,406	26,651	89,142	1,234,811
Fairness Doctrine and advertising restrictions only	-	−18.1	−26.5	−28.8	-	5,566	48,874	136,820	662,763	6,738,382
Health warnings only	-	−1.2	−1.3	−1.4	-	3,047	5,281	7,566	142,402	513,321
Media campaign s only	-	−1.0	−3.0	−3.3	-	3,040	8,889	14,240	168,547	851,383
Cessation treatment policies only	-	-	−3.9	−5.5	-	-	8,465	33,332	74,698	1,485,589
Youth access only	-	-	−1.7	−3.6	-	-	-	12,732	-	219,922
	1965	**1990**	**2012**	**2065**	**1965**	**1990**	**2012**	**2065**	**1965–2012**	**1965–2065**
Female	Smoking prevalence, %				Number of smoking attributable deaths					
No policies[a]	33.7	34.4	33.0	30.8	32,148	162,569	221,079	275,099	7,337,162	21,391,400
All policies[b]	33.7	26.3	15.2	10.8	32,148	156,585	174,981	101,961	6,711,816	14,086,564
	Change relative to no policies,[c] %				Number of deaths averted compared to no policies[d]					
All policies[b]	-	−23. 6	−55. 1	−64. 8	-	5,984	46,098	173,138	7,337,162	7,304,836
Price only	-	−5.4	−24. 1	−34. 4	-	80	13,862	85,189	6,711,816	2,608,330
Smoke free air only	-	−0.7	−5.4	−6.0	-	346	4,150	17,068	7,337,162	764,298
Fairness doctrine and advertising restrictions only	-	−16. 6	−26. 5	−28. 4	-	2,476	18,659	83,243	6,711,816	3,728,500
Health warnings only	-	−1.2	−1.3	−1.5	-	1,558	3,084	5,018	7,337,162	316,945

	1965	1990	2014	2065	1965	1990	2014	2065	1965–2014	1965–2065
Media campaigns only	-	−1.1	−3.0	−3.4	-	1,554	5,059	9,467	6,711,816	521,348
Cessation treatment policies only	-	-	−3.9	−5.1	-	-	5,049	20,820	7,337,162	931,428
Youth access only	-	-	−1.7	−4.1	-	-	-	8,034	-	110,812

[a] No policies scenario is modelled with the level of tobacco control policies unchanged since 1965.

[b] All policies scenario is modelled with all of the tobacco control policies actually implemented since 1965.

[c] The relative change to no policies computed was using the formula: (smoking rate under a policy scenario in the specified year – smoking rate with no policy change in the specified year)/smoking rate under with no policy change in the specified year.

[d] The number of deaths averted relative to no policies computed was using formula: number of smoking attributable deaths with no policy change – number of smoking attributable deaths under a policy scenario.