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Tobacco control policies are egalitarian: A vulnerabilities perspective on clean indoor air laws, cigarette prices, and tobacco use disparities

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ABSTRACT

This study models independent associations of state or local strong clean indoor air laws and cigarette prices with current smoker status and consumption in a multilevel framework, including interactions with educational attainment, household income and race/ethnicity and the relationships of these policies to vulnerabilities in smoking behavior. Cross sectional survey data are employed from the February 2002 panel of the Tobacco Use Supplement of the Current Population Survey (54,024 individuals representing the US population aged 15–80). Non-linear relationships between both outcome variables and the predictors were modeled. Independent associations of strong clean indoor air laws were found for current smoker status (OR 0.66), and consumption among current smokers (−2.36 cigarettes/day). Cigarette price was found to have independent associations with both outcomes, an effect that saturated at higher prices. The odds ratio for smoking for the highest versus lowest price over the range where there was a price effect was 0.83. Average consumption declined (−1.16 cigarettes/day) over the range of effect of price on consumption. Neither policy varied in its effect by educational attainment, or household income. The association of cigarette price with reduced smoking participation and consumption was not found to vary with race/ethnicity. Population vulnerability in consumption appears to be structured by non-white race categories, but not at the state and county levels at which the policies we studied were enacted. Clean indoor air laws and price increases appear to benefit all socio-economic and race/ethnic groups in our study equally in terms of reducing smoking participation and consumption.

Introduction

Tobacco remains the leading preventable cause of death and disease in the US (Armour, Woollery, Malarcher, Pechacek, & Husten, 2005). Health disparities are created by tobacco use, because it is increasingly concentrated among those with less education than a college degree, those with low income, and among whites and American Indians (Centers for Disease Control and Prevention, 1998; Fagan et al., 2004; Fagan, Moolchan, Lawrence, Fernander, & Ponder, 2007; Moolchan et al., 2007). Education above a high-school degree is associated with lower smoking prevalence, lower consumption, and increased likelihood of quitting among smokers (Escobedo & Peddicord, 1996; Fagan et al., 2007; Jefferis, Power, Graham, & Manor, 2004). Increased income is associated with smaller decreases in smoking prevalence, lower consumption among current smokers, and increased quit attempts (Barbeau, Krieger, & Soobader, 2004; Tauras, 2006). Blue collar and service workers are more likely to smoke than white collar workers (Barbeau et al., 2004a; Barbeau et al., 2004b; Townsend, Roderick, & Cooper, 1994). Low socio-economic status women tend to have lower quit rates than men or higher socio-economic status women (Graham, Inskip, Francis, & Harman, 2006; Jefferis et al., 2004). Using a life-course perspective in British and US studies, Graham and colleagues found that in smokers older than mid-20s, smoking-related disparities arise from quitting patterns, since so few people start smoking after that age (Graham & Der, 1999; Graham et al., 2006; Jefferis et al., 2004). Native Americans/Alaska Natives and whites (especially white males) have the highest prevalence and Intensity of smoking (Centers for Disease Control and Prevention, 1998; LaVeist, Thorpe, Mance, & Jackson, 2007; Tauras, 2006) and earliest age of initiation (DeCicca, Kenkel, & Mathios, 2000; Trinidad, Gilpin, Lee, & Pierce, 2004), while Latinos and Asians have the lowest smoking prevalence and intensity. Blacks have slightly lower smoking prevalence than whites. Blacks, Latinos and Asians have lower smoking intensity than whites and Native Americans/Alaska Natives (Centers for Disease Control and Prevention, 1998; Fagan et al., 2007; Tauras, 2006). Since the mid-1980s, tobacco control policies, particularly clean indoor air laws and tax increases (to increase cigarette price) have been implemented (Institute of

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Medicine, 2007). There is little information on the effects of these policies on health disparities (Tauras, 2007).

Although smoking rates have decreased overall, as of 2004 race/ethnic disparities in smoking participation have deepened since the late 1990s according to National Health Interview Survey data: whites and American Indians/Alaska Natives who have the highest prevalence of smoking participation have seen smaller relative decreases in smoking rates than blacks, Asian Americans and Latinos (Fagan et al., 2007). According to these same data, as of 2004 smoking rates among individuals with an undergraduate or graduate degree, disparities in smoking rates have decreased slightly for those with a high school diploma, GED or less education compared to those with college degrees. Those who attended high school for 4 years without a degree experienced virtually no decline during this same period. Finally, these data show decreases on average over the same period for individuals above and below the poverty line, indicating little change in economic disparities in smoking (Fagan et al., 2007).

A study published before any strong state clean indoor air laws were passed (Chaloupka, 1992) reported significant differences in smoking prevalence by the presence of a state clean indoor air policy only for men. A later study reported only white men responded to clean indoor air laws (Chaloupka & Pacula, 1999). A Massachusetts study reported that towns with a higher percentage of minority residents were more likely to have stronger restaurant smoking regulations (Skeer, George, Hamilton, Cheng, & Siegel, 2004), suggesting that at the local level, minorities may be better protected than whites by clean indoor air laws. A recent review of the tobacco control literature suggests that workplace smokefree policies do not have differential effects by income, education or race/ethnicity (Thomas et al., 2008). Some have found increased sensitivity of smoking status and consumption to cigarette prices among the poor (Centers for Disease Control and Prevention, 1998; Kandel, Kiros, Schaffran, & Hu, 2004; Thomas et al., 2008; Townsend et al., 1994) and among blacks and Latinos (Chaloupka & Pacula, 1999; Farrelly, Bray, Pechacek, & Woollery, 2001; Kandel et al., 2004), although a review of the effects of price on smoking in adults (Thomas et al., 2008) found no evidence of differential effects of smoking by race/ethnicity. Others found that price elasticity of smoking did not depend on socioeconomic status (Franks et al., 2007; Wasserman, Manning, Newhouse, & Winkler, 1991), including some studies suggesting that smoking may be insensitive to price (Borren & Sutton, 1992; Regidor, Pascual, & Gutiérrez-Fisac, 2007). Some studies suggest that those with higher education may be more sensitive to the price of cigarettes (Thomas et al., 2008).

We assess the independent associations of clean indoor air laws and cigarette price (which is affected by taxes), describe socioeconomic and race/ethnic disparities in cigarette use, and determine whether and how these policies affect disparities in tobacco use using a large nationally representative sample. We examine whether there is different variance around average group and policy effects because, following the 'vulnerabilities' perspective, greater extremes and uncertainty in outcomes implies population vulnerability to external stressors (Ahern, Galea, Hubbard, & Karpati, 2008; Galea, Ahern, & Karpati, 2005; Karpati, Galea, Awerbuch, & Levins, 2002; Levins & Lopez, 1999). The aims of our study are to consider disparities in tobacco control both by evaluating possible differences in the effects of clean indoor air laws and cigarette prices by different social circumstances, and by establishing whether vulnerabilities exist for smoking participation and consumption and, if so, whether these vulnerabilities covary with tobacco control policies.

We find that clean indoor air laws and cigarette prices are independently associated with reductions in smoking, that established patterns of education, income, and race/ethnic disparity in smoking are largely unaffected by either clean indoor air laws or price in terms of both mean effects and variance, and that clean indoor air policies and cigarette prices are generally neutral with regard to health disparities.

Methods

Data

Data on 54,024 self-respondents were collected via interview as part of the US Census Bureau's Tobacco Use Supplement of the Current Population Study (TUS CPS) in February 2002 (Table 1) (US Department of Commerce, Bureau of the Census, 2004). The data are a nationally representative sample of non-institutionalized civilian individuals i nested in 266 counties j, nested in 50 states plus the District of Columbia ($k = 51$). The household response rate for the February 2002 CPS was 93%. All dollar amounts reported in this paper are 2002 dollars.

Dependent variables

We use two measures of cigarette behavior: current smoker status among all respondents, and cigarettes smoked per day among current smokers. A histogram showed the number of cigarettes consumed per day among current smokers was log normal, so we use ln(cigarettes/day) as the dependent variable.

Independent variables

Policy variables

Data on strong clean indoor air laws in effect at time of interview were obtained from the American Lung Association's *State of*

Table 1
Descriptive statistics[a].

	All participants ($N = 54{,}024$)	Current smokers ($N = 10{,}654$)	% Missing
Dependent variables			
Current smoker (%)	19.5 (SE 0.40)	100	<1
Current smoker cigarettes/day		20 (IQR 10, 20)	21
Current smoker ln(cigarettes/day)		2.67 (SD 0.95)	21
Policy variables			
C, covered by strong clean indoor air law (%)	14.2 (SE 0.35)	10.1 (SE 0.30)	11
P, state price of cigarettes per pack ($)	3.47 (SD 0.50)	3.43 (SD 0.50)	0
Individual variables			
E, educational attainment (HS degree = 39)[b]	40 (IQR 39, 43)	40 (IQR 39, 43)	0
I, household income ($10,000)	5.36 (SD 5.09)	4.33 (SD 4.44)	11
B, black (%)	12.2 (SE 0.33)	12.0 (SE 0.33)	0
W, white (%)	82.8 (SE 0.38)	83.9 (SE 0.37)	0
N, American Indian/Aleut/Eskimo (%)	1.1 (SE 0.10)	1.7 (SE 0.13)	0
A, Asian Pacific Islander (%)	3.9 (SE 0.19)	2.4 (SE 0.15)	0
L, Latino (%)	11.3 (SE 0.32)	7.9 (SE 0.27)	1
Y, age (years)	43.5 (SD 21.6)	40.6 (SD 18.1)	0
S, female (%)	51.8 (SE 0.50)	46.7 (SE 0.50)	0

[a] From combined imputations.
[b] The CPS educational attainment scale (code): no education (31), first, second, third or fourth grade (32), fifth or sixth grade (33), seventh or eighth grade (34), ninth grade (35), tenth grade (36), eleventh grade (37), twelfth grade no diploma (38), high school diploma or equivalent (39), some college but no degree (40), occupational associate degree (41), academic associate degree (42), bachelor's degree (43), master's degree (44), professional degree (45), or doctorate degree (46).

Tobacco Control 2002 (American Lung Association, 2003) and local ordinances from the American Nonsmokers' Rights Foundation Local Tobacco Control Ordinance database. Strong clean indoor air laws include 100% prohibition without exception of smoking in public and private workplaces (including non-hospitality work sites like manufacturing and office sites among others), restaurants (with and without attached bars), and bars and taverns. The TUS CPS geographic data indicate county, but not city. However, for the population surveyed in February 2002 all counties with at least one city that had passed a strong clean indoor air ordinance were also covered by either countywide or state laws. Therefore, clean indoor air variable equaled 1 if a respondent was covered by a city, county or state clean indoor air law, and equaled 0 otherwise.

We obtained price from the average state cigarette prices per pack from *The Tax Burden on Tobacco* (Orzechowski & Walker, 2006). Five states (Connecticut, New York, Rhode Island, Utah, and Washington) increased state excise taxes during this fiscal year; linear interpolation accounting for date of tax change was used to estimate the price per pack in February 2002.

Individual variables

The TUS CPS data provides a hybrid 16 point ordinal measure of educational attainment, with lower values approximately describing years of primary and secondary school completed and higher values representing a high-school diploma or equivalent, some college but no degree, and college and higher degrees (Table 1).

The TUS CPS measures annual household income from wages with a 14 point scale ranging from $0–5000, to $75,000 or more. We recoded each value to the midpoint of each range, and estimated the midpoint of the open-ended highest category for each state in order to analyze household income as an interval variable using Pareto's method as employed by the Census Bureau (Henson, 1967; Parker & Fenwick, 1983). Recent research using the CPS (Korinek, Mistiaen, & Ravallion, 2006) suggests that higher income households are less likely to report income. Uncorrected, such patterned non-response would tend to decrease the confidence around estimates of effect for higher incomes, and bias the average association between household income and smoking participation and consumption towards rates and levels associated with lower incomes with less. We performed multiple-imputation to address the biases resulting from non-response.

Race/ethnicity was described by four mutually exclusive categories (white, black, Asian/Pacific Islander, and American Indian/Aleutian/Eskimo), together with a separate variable for Latino/non-Latino (US Department of Commerce, Bureau of the Census, 2004). Years of age and sex (female coded as 1) were also included.

Model development

Preliminary analysis of both non-imputed and a single imputed data set suggested that some of the relationships between the independent and dependent variables were not linear. Non-linearities in the responses are of direct interest (see Figs. 1–3.) and violations of the assumption of linearity may bias both the mean and variance regression estimates. To investigate the existence and nature of potential non-linear relationships without making assumptions beyond additivity about the specific nature of these relationships, we analyzed both dependent variables as functions of each predictor (see "Non-parametric regression models" in the online supplementary document for details).

Non-linear least squares regression models (see Supplement for details) confirmed these non-linear relationships (Figs. 1–3). Both dependent variables were modeled as piecewise linear functions of price. Educational attainment's effect on current smoker status was modeled as a cubic polynomial and its effect on ln(cigarettes/day) was modeled as a linear threshold. The effect of household income on current smoker status was modeled as a quadratic equation with a break point. Age was modeled as quadratic for both outcomes.

Primary analysis

Multilevel modeling (Duncan, Jones, & Moon, 1998; Goldstein, 2003) permits variance to be modeled both in terms of data hierarchy (e.g., How much of the variation in outcome is at the level of individuals versus counties versus states) and explicitly as a function of independent variables (e.g., Does variance in outcome increase or decrease with some measure of state policy? Does variance change with individual educational attainment?). Consistent with the multilevel modeling literature, we describe the underlying relationship between the dependent and independent variables with a fixed part that represents the average slope and intercept across all groups (including policy interactions with social circumstances) and a random part which summarizes the variance of slopes and intercepts (for continuous variables) or effects (for categorical variables) between states, counties and individuals and a covariance which assesses the degree to which the two distributions are related (Duncan, Jones, & Moon, 1998; Snijders, 2005).

Tobacco use and tobacco control policy vulnerability questions are answered first by modeling the variance in current smoker status and ln(cigarettes/day) for different social circumstances. For those social circumstances with significant variance in tobacco use, we can then model how the effects of policy on tobacco use covary with social circumstance at the levels of policy implementation. For the most egalitarian policies, the covariances will be close to zero across all social groups (i.e., not associated differences in vulnerability); significant relationships between these variances may indicate amelioration or exacerbation of tobacco use disparities (i.e., associated with decreasing or increasing vulnerability for groups defined by specific social circumstances).

In order to characterize the conditional effects of our independent variables on current smoking status and current smoking intensity, we provide fixed effect-only models of current smoker status (Eq. (1)) and ln(cigarettes/day) among current smokers (Eq. (2)). These models describe average effects of policy, individual-level factors and 12 first-order interactions between the two policy variables (clean indoor air law, C and price, P) and educational attainment (E), household income (I), and race/ethnicity (B, N, A, and L), including the non-linear specifications described above (see Supplement Tables S2 and S4).

$$\begin{aligned}\text{logit}(U) = {} & \alpha_0 + \alpha_C C + \alpha_P P + \alpha_{P_\text{b}} P_\text{b} + \alpha_E E + \alpha_{E^2} E^2 + \alpha_{E^3} E^3 + \alpha_I I \\ & + \alpha_{I_\text{b}^2} I_\text{b}^2 + \alpha_B B + \alpha_N N + \alpha_A A + \alpha_L L + \alpha_{\ldots} \text{Interactions} \\ & + \alpha_{Y_B^2} Y_B^2 + \alpha_{Y_W^2} Y_W^2 + \alpha_{Y_N^2} Y_N^2 + \alpha_{Y_A^2} Y_A^2 + \alpha_S S \qquad (1)\end{aligned}$$

$$\begin{aligned}D = {} & \beta_0 + \beta_C C + \beta_P P + \beta_{P_\text{b}} P_\text{b} + \beta_{E_\text{b}} E_\text{b} + \beta_I I + \beta_B B + \beta_N N + \beta_A A + \beta_L L \\ & + \beta_{\ldots} \text{Interactions} + \beta_Y Y + \beta_{Y^2} Y^2 + \beta_S S + \zeta \qquad (2)\end{aligned}$$

where

U smokes cigarettes (1 = smoker)
D ln(cigarettes/day)
C strong clean indoor air coverage (effect coded)
P state average price of cigarettes in the respondent's state ($, centered)
P_b change in the slope of P after the break point, given by $\max(P - \theta_P, 0)$
θ_P breakpoint at which the effect of P changes slope

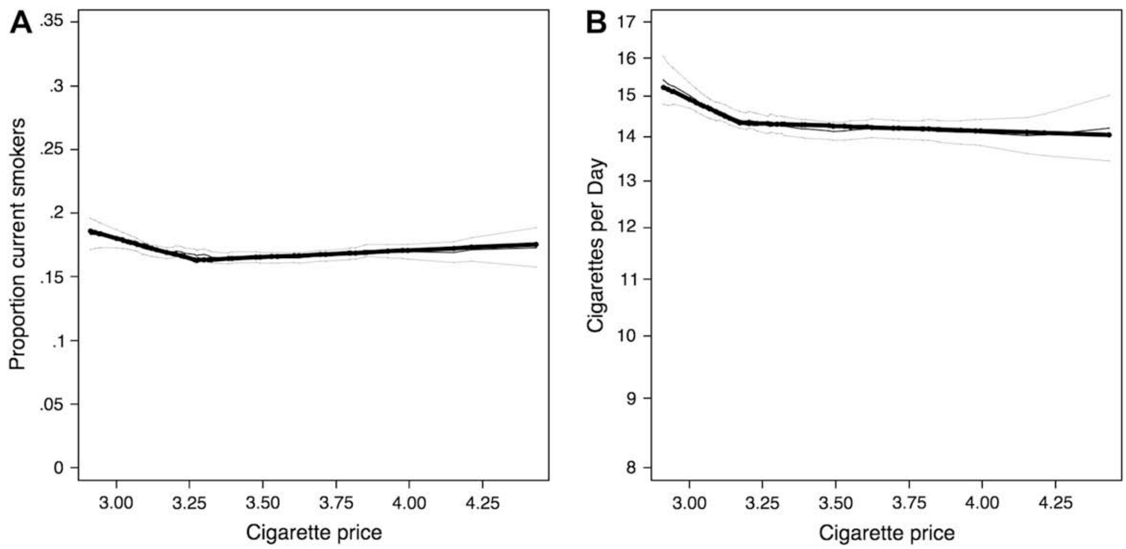

Fig. 1. Non-linear regression models (thick black lines) of the effect of cigarette price per pack (dollars) on current smoking (A), and ln(cigarettes/day) (B) from Eqs. S1a,S1b overlaid on the results of non-parametric models (thin black lines) with pointwise 95% confidence intervals (thin grey lines) from Eq. S1a,S1b. A piecewise linear specification reflects the initial decreasing effect of price, followed by a change in effect evident in both models. Eq. S2a estimated that the change in effect of price on current smoker status was at \$3.28 (SE 0.08) and Eq. S2b estimated that saturation for the effect of price on ln(cigarettes/day) was at \$3.17 (SE 0.42).

E educational attainment (centered)
E_b change in the slope of E after the break point, given by $\max(E - \theta_E, 0)$
θ_E breakpoint at which the effect of E changes slope
I household income (\$10,000, centered)
I_b^2 quadratic effect of I after the break point, given by $\max(I - \theta_I^2, 0)^2$
θ_I break point at which the effect of I includes a quadratic term
B black (effect coded)
N American Indian/Aleut/Eskimo (effect coded)
A Asian/Pacific Islander (effect coded)
L Latino (effect coded)
Y age (years, centered on mean)
Y_B age for blacks (years, centered on group mean)
Y_W age for whites (years, centered on group mean)
Y_N age for American Indians/Aleuts/Eskimo (years, centered on group mean)
Y_A age for Asians/Pacific Islanders (years, centered on group mean)
S female (effect coded)
ζ model error, assumed distributed normal

Our fixed effects models were expanded to incorporate random effects that estimate how the effects of educational attainment, household income, and race/ethnicity on current smoker status may vary between counties and states, and for ln(cigarettes/day), also between individuals. Significant variance terms in these group variance models would indicate that members of some groups

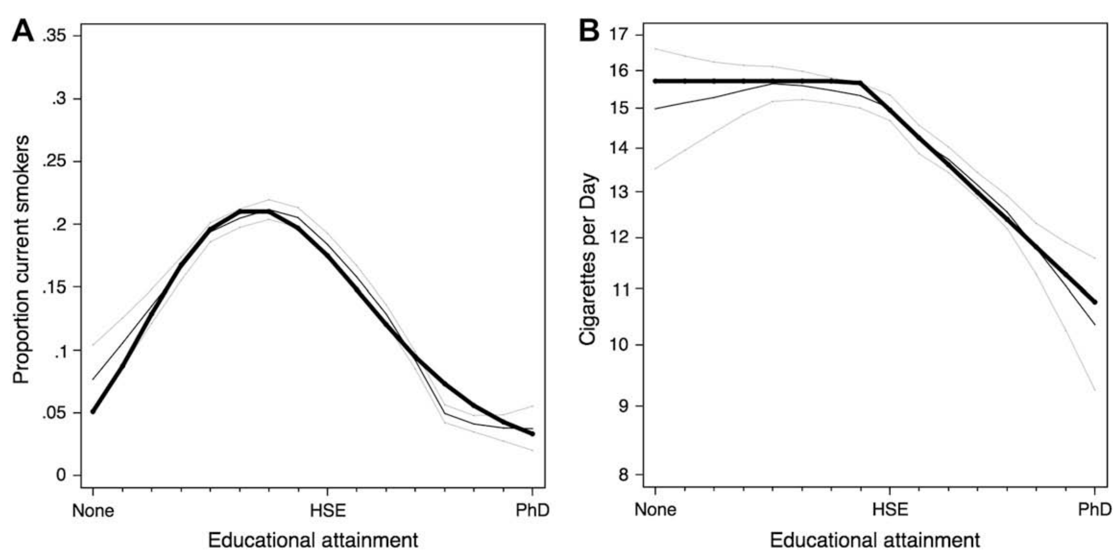

Fig. 2. Non-linear regression models (thick black lines) of the effect of educational attainment (see Table 1 for coding details) on current smoking (A), and ln(cigarettes/day) (B) from Eqs. S1a,S1b overlaid on the parallel non-parametric models (thin black lines) with pointwise 95% confidence intervals (thin grey lines) from Eqs. S1a,S1b. A fully cubic specification models educational attainment's effect on current smoker status, producing the fit in (A). A linear threshold of ln(cigarettes/day) reflects the initial unresponsiveness of consumption to educational attainment followed by a strong negative effect at 4 years of high school education or more. Eq. S2b estimated that the change in effect of educational attainment on ln(cigarettes/day) status was at twelfth grade, but no diploma, and higher (38, SE 0.71).

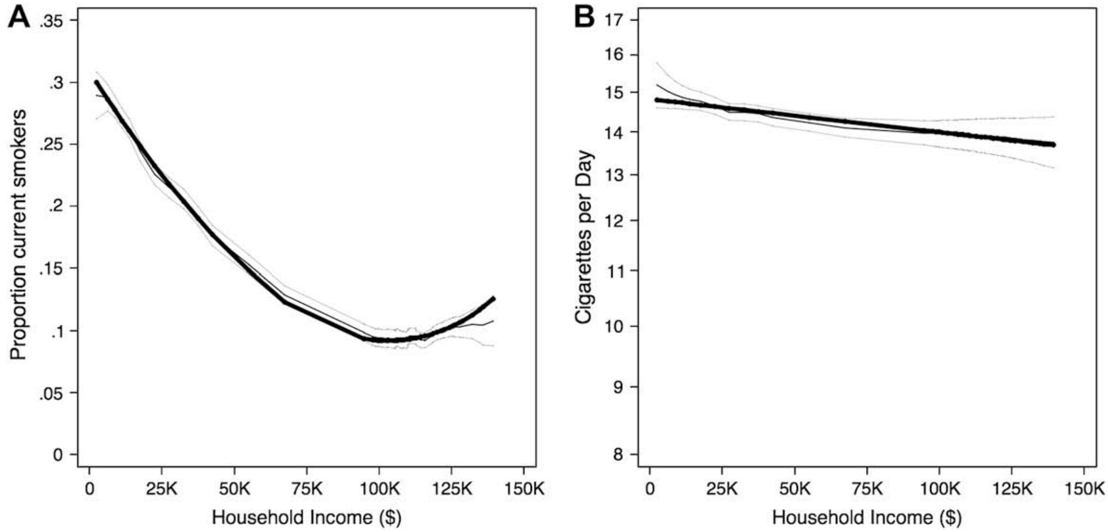

Fig. 3. Non-linear regression models (thick black lines) of the effect of household income (dollars) on current smoking (A), and ln(cigarettes/day) (B) from Eqs. S1a,S1b overlaid on the parallel non-parametric models (thin black lines) with pointwise 95% confidence intervals (thin grey lines) from Eqs. S1a,1b. A linear specification with a quadratic change in effect models current smoker status at $70K (SE 7.1K) to model the non-parametric relationship in (A). A linear specification models the effect of household income on ln(cigarettes/day) as shown in (B).

experience greater uncertainty in outcome than others between states, counties, or individuals. Random effects for race/ethnicity were separate coded for parsimony.

The terms μ and ν in Eq. (3) represent random effects at the levels of counties and states, respectively. The lowercase terms b, w, n, and a represent separate coding of race (i.e. 0 or 1), and the terms l and m represent separate coding of Latino and non-Latino.

$$\begin{aligned}\text{logit}\Big(U_{ijk}\Big) = {} & \alpha_0 + \alpha_C C + \alpha_P P + \alpha_{P_b} P_b + \alpha_E E + \alpha_{E^2} E^2 + \alpha_{E^3} E^3 \\ & + \alpha_I I + \alpha_{I_b^2} I_b^2 + \alpha_B B + \alpha_N N + \alpha_A A + \alpha_L L \\ & + \alpha_{\ldots}\text{Interactions} + \alpha_{Y_B^2} Y_B^2 + \alpha_{Y_W^2} Y_W^2 + \alpha_{Y_N^2} Y_N^2 \\ & + \alpha_{Y_A^2} Y_A^2 + \alpha_S S + \nu_{E,k} E + \nu_{I,k} I + \nu_{b,k} b + \nu_{w,k} w \\ & + \nu_{n,k} n + \nu_{a,k} a + \nu_{l,k} l + \nu_{m,k} + \mu_{E,jk} E + \mu_{I,jk} I \\ & + \mu_{b,jk} b + \mu_{w,jk} w + \mu_{n,jk} n + \mu_{a,jk} a + \mu_{l,jk} l + \mu_{m,jk} m \end{aligned} \quad (3)$$

The terms ζ, η, and κ in the group variance model of ln(cigarettes/day) represent random effects at the levels of individual, county and state (Eq. (4)). Covariances are constrained to be zero for Latinos because when covariance terms between Latinos and the race categories were added to this model (not presented), we did not find substantively different variance estimates. The same is true for education and income.

$$\begin{aligned} D_{ijk} = {} & \beta_0 + \beta_C C + \beta_P P + \beta_{P_b} P_b + \beta_{E_b} E_b + \beta_I I \\ & + \beta_{I_b^2} I_b^2 + \beta_B B + \beta_N N + \beta_A A + \beta_L L \\ & + \beta_{\ldots}\text{Interactions} + \beta_Y Y + \beta_{Y^2} Y^2 + \beta_S S \\ & + \eta_{E,k} E + \eta_{I,k} I + \eta_{b,k} b + \eta_{w,k} w + \eta_{n,k} n \\ & + \eta_{a,k} a + \eta_{l,k} l + \eta_{m,k} m + \kappa_{E,jk} E + \kappa_{I,jk} I + \kappa_{b,jk} b \\ & + \kappa_{w,jk} w + \kappa_{n,jk} n + \kappa_{a,jk} a + \kappa_{l,jk} l + \kappa_{m,jk} m \\ & + \zeta_{E,ijk} E + \zeta_{I,ijk} I + \zeta_{b,ijk} b + \zeta_{w,ijk} w + \zeta_{n,ijk} n \\ & + \zeta_{a,ijk} a + \zeta_{l,ijk} l + \zeta_{m,ijk} m \end{aligned} \quad (4)$$

These variance estimates describe a population's vulnerability to the outcome at a given level of the data hierarchy. For example, in Eq. (4) the estimated county-level standard deviation in ln(cigarettes/day) for people with high education $E = 6.7$ (corresponding to a doctoral degree in the centered data), household income $I = 2.5$ ($67,500 per year) and who are white is described by the sum of the standard deviations times the values of their corresponding variables, plus twice the covariances (which in this case equal 0) times their corresponding variables' products, $6.7\sigma_{E,jk} + 2.5\sigma_{I,jk} + \sigma_{w,j}$.

We found no significant state-level or county-level variation in the effects of educational attainment, household income or race/ethnicity on either current smoker status or consumption (Table 3). Therefore we did not estimate policy/social group covariance models for either outcome.

Eqs. (1)–(4) were estimated using the restricted iterative generalized least squares maximum likelihood algorithm in MLwiN 2.02 (Rabash, Steele, Browne, & Prosser, 2004). We adjust p-values for multiple comparisons using the Holm method (Holm, 1979), with each family of comparisons being the set of presented estimates for each model for a family wise error rate of 0.05.

Missing data and imputation

In order to minimize analytic biases introduced by case-wise deletion of observations with missing data, we employed multiple imputation using Stata 9.2 (StataCorp, 2005) and the ice package (Royston, 2004, 2005) to create five data sets for analysis with combined results (Rubin, 1976, 1996; Schafer, 1999). Reported parameter estimated and confidence intervals thus account for uncertainty introduced by missing data.

Results

Fixed effect-only models of current smoker status

Table 2a presents estimates for a fixed effect model of current smoker status with the only significant interaction terms included (see Supplement for all interactions). Strong clean indoor air policies are associated with a significant decrease in the odds of smoking (OR 0.66; 95% CI 0.60, 0.73). There was an interaction between the presence of a clean indoor air law and black race for smoker status ($p = 0.033$), but when combined with the fact that blacks were less likely to smoke (albeit not significantly), there was not a significant effect of the overall odds that blacks were smokers associated with the presence of a clean indoor air law (OR 1.21; 95% CI 0.94, 1.55) (see Supplement for calculations). There were no significant interaction terms between clean indoor air policy for the other race/ethnicity categories. The effect of clean indoor air laws did not change with education or household income. The results were the same when we stratified by sex (results not presented).

The OR for smoking given a 10¢ increase in price was 0.95 (95% CI 0.93, 0.97) below $3.28/pack; this relationship ends above that price (Fig. 1a). The OR for smoking for the highest price in the range where there was a price effect ($3.28/pack) versus lowest price ($2.91/pack) was 0.83 (95% CI 0.78, 0.88). The association of cigarette price with smoker status did not change with educational attainment, household income or race/ethnicity. There was no interaction between clean indoor air coverage and cigarette price (model not shown).

Including immigrant status in the model made Latinos slightly more likely to be smokers (model not presented), but they still had significantly lower rates than the overall population. (Immigrants in general were less likely to smoke.) The Latino × immigrant status interaction term was not significant, implying that immigrant effects on smoking status are not different for Latinos compared to non-Latinos.

Fixed effect-only models of ln(cigarettes/day)

We present the results of two fixed-effect only models of ln(cigarettes/day) among current smokers in Table 2b, converted to cigarettes/day for ease of interpretation. Strong clean indoor air laws were associated with a significant decrease of −2.36 cigarettes/day (95% CI −2.43, −2.29). We found a decline of −1.16 cigarettes/day (95% CI −0.40, −2.03) over the range for which we found an effect of price of current smoker status, with average consumption ranging from 13.1 (95% CI 12.48, 13.78) at a price of $3.17/pack to 14.3 (95% CI 12.9, 15.8) at $2.92/pack (Fig. 1b). We found no interaction between either strong clean indoor air coverage or cigarette price and educational attainment, household income, or race/ethnicity (see tables in the Supplement). This finding was repeated in analyses stratified by sex (not presented).

Table 2a
Selected variables from fixed effect-only logistic regression model of current smoker status (Eq. (1)): full results in Table S1; OR (95% CI uncorrected for multiple comparisons) Holm-adjusted p-values[a].

	OR for current smoker status	p
$e^{2\alpha_C}$, strong clean indoor air coverage	0.661 (0.656, 0.665)	0.010
e^{α_P}, centered price per pack of cigarettes (¢)	0.995 (0.995, 0.995)	0.038
$e^{\alpha_{P_b}}$, change in price's effect at $3.28/pack	1.006 (1.006, 1.006)	0.058
e^{α_E}, centered educational attainment[b]	0.839 (0.839, 0.839)	<0.001
$e^{\alpha_{E^2}}$, educational attainment^2	0.976 (0.976, 0.976)	<0.001
$e^{\alpha_{E^3}}$, educational attainment^3	1.001 (1.001, 1.001)	0.042
e^{α_I}, centered household income ($10,000s)	0.842 (0.842, 0.842)	<0.001
$e^{\alpha_{I^2}}$, household income^2 effect at $70,000	1.028 (1.028, 1.028)	<0.001
$e^{2\alpha_B}$, black	0.945 (0.928, 0.963)	ns
$e^{2\alpha_N}$, Native American[c]	1.370 (1.268, 1.479)	ns
$e^{2\alpha_A}$, Asian/Pacific Islander	0.504 (0.492, 0.516)	0.030
$e^{2\alpha_L}$, Latino	0.473 (0.472, 0.474)	<0.001
$e^{2\alpha_{CB}}$, clean indoor air law × black	1.705 (1.680, 1.731)	0.033
$e^{2\alpha_{CN}}$, clean indoor air law × Native American	0.711 (0.658, 0.768)	ns
$e^{2\alpha_{CA}}$, clean indoor air × Asian/Pacific Islander	0.817 (0.801, 0.833)	ns

[a] Holm adjustment is a sequential procedure with a stopping criterion; all parameter estimates with p-values larger than that of the first rejected p-value are rejected; such rejection is indicated by "ns".
[b] See Table 1 for coding.
[c] Includes American Indians, Aleutians, and Eskimos.

Table 2b
Selected variables from fixed effect-only linear regression model of cigarette consumption among current smokers (Eq. (2)): full results in Table S3; exponentiated coefficients (95% CI uncorrected for multiple comparisons) Holm-adjusted p-values[a].

	Multiplier for consumption cigarettes/day	p
$e^{2\beta_C}$, strong clean indoor air coverage	0.826 (0.826, 0.827)	0.001
e^{β_P}, centered price per pack of cigarettes (¢)	0.997 (0.997, 0.997)	0.015
$e^{\beta_{P_b}}$, change in price's effect at $3.20/pack	1.003 (1.003, 1.003)	0.031
$e^{\beta_{E_b}}$, threshold educational attainment at 12th grade[b]	0.961 (0.961, 0.961)	<0.001
e^{β_I}, centered household income ($10,000s)	0.992 (0.992, 0.992)	0.015
$e^{2\beta_B}$, black	0.877 (0.875, 0.878)	0.156
$e^{2\beta_N}$, Native American[c]	1.006 (1.000, 1.011)	0.960
$e^{2\beta_A}$, Asian/Pacific Islander	0.697 (0.683, 0.712)	0.310
$e^{2\beta_L}$, Latino	0.606 (0.605, 0.606)	<0.001

[a] Holm adjustment is a sequential procedure with a stopping criterion; all parameter estimates with p-values larger than that of the first rejected p-value are rejected; such rejection is indicated by "ns".
[b] See Table 1 for coding.
[c] Includes American Indians, Aleutians, and Eskimos.

Latino smokers' consumption increased by a factor of about 1.04 if we included immigrant status in the model, with immigrants significantly less likely to smoke (model not presented). A Latino immigrant status interaction term was not significant, implying that immigrant effects on smoking status are not different for Latinos.

Group variance models

Group level variance models show no significant state-level or county-level variation in current smoker status or in cigarettes consumed per day for race/ethnicity, educational attainment, or household income (Table 3). Smoking participation and intensity do not vary appreciably between states or between counties for these social circumstances. Several variance terms in both models were too small to be estimated in one or more imputed data sets (Table 3).

We found significant individual-level variance in cigarettes/day only for non-white race categories. Among the race categories, variability in consumption was highest for American Indians/Aleuts/Eskimo (varies by a factor of 2.07), and Asians/Pacific Islanders (varies by a factor of 1.93), and next highest for blacks (varies by a factor of 1.87).

There was no significant individual-level variance in the effects of educational attainment or household income on consumption. The differences in individual-level variability between different race/ethnic categories are much larger than any other variance estimate at the state or county level. This result implies that differences in race/ethnic experiences among current smokers reflects much greater vulnerability in cigarette consumption than educational attainment and household income, or to geographic vulnerabilities and that state and county level-level conditions, including tobacco control policies, are not driving cigarette use disparities.

Discussion

We found that clean indoor air policies—whether implemented by state or locality—are associated with significantly lower rates of smoking and consumption among smokers and that price increases are associated with lower smoking participation and consumption up to a threshold for each, after which the effects of price become highly uncertain. The effect of clean indoor air laws on smoking status (OR 0.66) was larger than the effect of cigarette prices over the range of prices at which we found smokers to be price sensitive (OR 0.83 for $2.91 to $3.28).

Our estimate of the effect of clean indoor air laws is stronger than that reported by Fichtenberg and Glantz (2002), who reported an absolute decrease of about 3.1% in smoking prevalence associated with smoke-free workplaces (they did not report ORs), corresponding to an approximate OR of 0.80 assuming a prevalence decrease from about 23.8 to 20.0%. We found a weaker association of strong clean indoor air laws with consumption among smokers (−2.36 cigarettes/day) than the −3.1 cigarettes/day (95% CI −2.4, −3.8) reported by Fichtenberg and Glantz. Our finding conflicts with the study of CPS TUS data from 1992 to 1999 by Tauras (2006), who found that state clean indoor air laws did not to predict smoking participation. This difference is likely due the limited number of strong state-level clean indoor air laws during the years Tauras studied and the fact that he did not consider the effects of the many strong local clean indoor air laws that were in effect at the time.

We found the effect of clean indoor air legislation on consumption (−2.36 cigarettes/day) to be comparable to, though larger than, the effect of cigarette price (−1.16 cigarettes/day) over the $0.36 range which we found smokers to be price sensitive. This relationship of cigarette price to consumption is stronger by almost an order of magnitude than that found by Tauras (2006). Over the ranges at which individuals were estimated to respond to price ($2.91–3.28 for smoking participation, and $2.91–3.17 for smoking consumption), elasticities calculated from our estimates are within the range of those in the published literature (Chaloupka & Warner, 1999; Gallet & List, 2003). We calculated a price-elasticity of participation of −0.41 (α_P*[1 − Pr(U)], with Pr(U) only for those individuals residing in states with price ≤$3.28) over the range for which price has an effect (Fig. 1a), and a price elasticity of demand of −0.9 9 (β_P*E(P), with E(P) only for those individuals residing in states with price ≤$3.17). Our findings suggest that increases in cigarette taxes should not be uncritically assumed to automatically decrease smoking participation of consumption. Further study should evaluate the thresholds of price's effects.

We find disparities in mean smoking participation and consumption rates by educational attainment, household income and race/ethnicity, generally agreeing with those in the literature. Our estimated effects of educational attainment are consistent with existing studies (Centers for Disease Control and Prevention, 1998; Fagan et al., 2007) showing increasing likelihood of smoking with increased attainment until at least 4 years of high school education, and with additional attainment thereafter associated with less smoking participation and showing decreasing smoking consumption accompanying increased educational attainment beginning after about 4 years of high school. Smoking prevalence decreases with household income, although this decrease attenuates for households with incomes above $70,000. Consumption also decreases linearly with household income. Patterns in smoker status by race/ethnicity reflect those in the published literature: blacks, Asian/Pacific Islanders and Latinos all are less likely to be smokers than whites and American Indians/Aleuts/Eskimo, with Latinos being least likely to smoke (Centers for Disease Control and Prevention, 1998; Fagan et al., 2007). We found that patterns by race/ethnicity in cigarette consumption correspond to those in the published literature: blacks, Asian/Pacific Islanders and Latinos all smoke less than whites and American Indians/Aleuts/Eskimo, with Latinos smoking much less (Centers for Disease Control and Prevention, 1998; Fagan et al., 2007).

Table 3
Estimated variance factors for the group variance models of current smoking status, and ln(cigarettes/day) for race/ethnicity, educational attainment, and household income (Eqs. (3),(4)): variance factor (95% CI uncorrected for multiple comparisons) Holm-adjusted P-values[a].

	Current smoker status ($N = 54{,}024$)	p	Cigarettes per day ($N = 10{,}674$)	p
State level terms				
$e^{\sigma_{\nu,E}}$, educational attainment	1.017 (1.017, 1.017)	ns	1.009 (1.009, 1.009)	ns
$e^{\sigma_{\nu,I}}$, household income ($1000)	1.012 (1.012, 1.012)	ns[c,1]	1.004 (1.004, 1.004)	ns[c,3]
$e^{\sigma_{\nu,b}}$, black	1.120 (1.117, 1.123)	ns	1 (na)	[b]
$e^{\sigma_{\nu,w}}$, white	1.072 (1.072, 1.073)	ns	1.011 (1.011, 1.011)	ns[c,4]
$e^{\sigma_{\nu,n}}$, American Indian/Aleut, Eskimo	1.617 (1.434, 1.898)	ns[c,2]	1.130 (1.128, 1.133)	ns[c,2]
$e^{\sigma_{\nu,a}}$, Asian/Pacific Islander	1.415 (1.378, 1.456)	ns	1.065 (1.065, 1.066)	ns[c,4]
$e^{\sigma_{\nu,l}}$, Latino	1.034 (1.034, 1.034)	ns[c,2]	1.114 (1.113, 1.115)	ns
$e^{\sigma_{\nu,m}}$, Non-Latino	1.026 (1.026, 1.026)	ns[c,2]	1.032 (1.032, 1.032)	ns[c,1]
$e^{\sigma_{\mu,E}}$, educational attainment	1.041 (1.041, 1.041)	0.226	1.007 (1.007, 1.007)	ns[c,2]
$e^{\sigma_{\mu,I}}$, household income ($1000)	1.030 (1.030, 1.030)	0.390	1.030 (1.030, 1.030)	ns[b]
$e^{\sigma_{\mu,b}}$, black	1.277 (1.266, 1.289)	ns	1.049 (1.049, 1.050)	ns[c,1]
$e^{\sigma_{\mu,w}}$, white	1.190 (1.187, 1.192)	0.189	1.013 (1.013, 1.013)	ns[c,3]
$e^{\sigma_{\mu,n}}$, American Indian/Aleut, Eskimo	1.927 (1.700, 2.250)	0.900	1.043 (1.043, 1.044)	ns[c,3]
$e^{\sigma_{\mu,a}}$, Asian/Pacific Islander	1.137 (1.133, 1.142)	ns	1.056 (1.055, 1.056)	ns[c,3]
$e^{\sigma_{\mu,l}}$, Latino	1.410 (1.393, 1.428)	0.061	1.100 (1.099, 1.102)	ns[c,1]
$e^{\sigma_{\mu,m}}$, Non-Latino	1.098 (1.097, 1.099)	ns	1.015 (1.015, 1.015)	ns[c,2]
Individual level terms				
$e^{\sigma_{\epsilon,E}}$, educational attainment	1.034 (1.034, 1.034)	ns		
$e^{\sigma_{\epsilon,I}}$, household income ($1000)	1.348 (1.281, 1.433)	ns		
$e^{\sigma_{\epsilon,b}}$, black	1.865 (1.798, 1.939)	<0.001		
$e^{\sigma_{\epsilon,w}}$, white	1.796 (1.68, 1.937)	0.277		
$e^{\sigma_{\epsilon,n}}$, American Indian/Aleut, Eskimo	2.067 (1.966, 2.182)	<0.001		
$e^{\sigma_{\epsilon,a}}$, Asian/Pacific Islander	1.925 (1.802, 2.073)	0.010		
$e^{\sigma_{\epsilon,l}}$, Latino	1.513 (1.454, 1.58)	ns		
$e^{\sigma_{\epsilon,m}}$, Non-Latino			1 (na)	[b]

[a] Holm adjustment is a sequential procedure with a stopping criterion; all parameter estimates with p-values larger than that of the first rejected p-value are rejected; such rejection is indicated by "ns".
[b] Zero terms indicate that there is no variance for the corresponding fixed effect at this level (Duncan, Jones, & Moon, 1998; Twisk, 2006).
[c] This term estimated zero variance for the indicated number of imputed data sets.

The absence of interactions between clean indoor air laws or cigarette prices and social circumstances are consistent with the idea that clean indoor air and cigarette taxes are not creating (or mitigating) disparities in cigarette use. This conclusion agrees with a recent review of the literature concerning clean indoor air and adds another study to those finding little or differential effects of price on adult smoking participation and consumption (Thomas et al., 2008). Thus, to address socio-economic and race/ethnic disparities in cigarette use, a tobacco control program will need to complement broad policies that reduce overall smoking participation and consumption with focused interventions to address higher tobacco use in selected populations.

The possible interaction effect for smoking participation for blacks living under strong clean indoor air laws may be a reflection of the much higher jobless rate for blacks than other race/ethnicity groups (US Department of Labor, Bureau of Labor Statistics, 2008). Because our measure of strong clean indoor air laws was defined in terms of smoking in places of employment, we stratified our analysis by employment status and found that this interaction became non-significant for employed blacks, while the effect of clean indoor air laws was still positive and significant for unemployed blacks (details not presented).

The higher variability in cigarette consumption for Asians/Pacific Islanders implies that those race/ethnic groups of smokers with the lowest mean cigarette consumption still encompass heavy smokers. The high variability among American Indians/Aleuts/Eskimo who have high rates of consumption suggests that this is a diverse population, as has been noted elsewhere in the literature (Fagan et al., 2007). Blacks also have a significantly non-zero variability, but this is not much larger than the non-significant group variability among whites.

The literature has a tradition of using linear measures of independent variables. As we have shown (see Figs. 1–3), an assumption of linearity may poorly reflect the relationships in the data and can bias variance estimates. Non-parametric models produced evidence of non-linear relationships between educational attainment and both smoking participation, and consumption among smokers. We also found that the association between cigarette price and participation and consumption saturates.

We have described differential vulnerabilities to cigarette use and consumption among smokers by race/ethnicity at the individual level. These disparities appear absent at the state and county levels for both outcomes. For consumption, vulnerability in cigarette use appears structured by experiences in non-white race categories.

Limitations

We have a small sample of states (51) and only a moderate sample of counties (266). We would also prefer race/ethnic data that reflected national or regional origin more than overly inclusive categories such as Asian/Pacific Islander. Because our data are cross-sectional we must be cautious about making causal inferences in our analyses. With longitudinal data we could both include hypotheses concerning changes in consumption, and initiating and quitting smoking, and be more equipped to make causal inferences about tobacco control policies and smoking behavior. Finally, local-level price data would be highly desirable for more valid inference about the effects of cigarette price of cigarette use and consumption. Recent research demonstrates that cumulative state tobacco control expenditures predict decreases in smoking (Farrelly, Pechacek, Thomas, & Nelson, 2008; Lightwood, Dinno, & Glantz, 2008). Cumulative expenditures for state tobacco control programs for the two and a half years preceding February, 2002 were obtained from the American Lung Association (2003). This imperfect measure of total cumulative expenditures on state tobacco control was highly correlated with our measure of clean indoor air laws, leading to colinearity in the regression models. For this reason, we omitted state tobacco control program expenditures from our analyses.

Conclusion

Clean indoor air laws and cigarette price had independent associations with decreased smoking prevalence and decreased consumption among smokers. Neither policy varied in its effect by educational attainment, or household income. The association of cigarette price with reduced smoking participation and consumption was not found to vary with race/ethnicity. Population vulnerability in consumption appears to be structured by non-white race categories, but not at the state and county levels at which the policies we studied were enacted. Clean indoor air laws and price increases appear to benefit all socio-economic and race/ethnic groups in our study equally in terms of reducing smoking participation and consumption.

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Appendix A. Supplemental material

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