The Effect of Smoking on Mental Health

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***Objectives*: The disproportionately high smoking prevalence among persons with mental health problems has raised a concern that this population is at increased risk for smoking-related illness. We investigated the effect of smoking on mental health among US adults aged 18 and older using the 2000-2010 Behavioral Risk Factor Surveillance System (BRFSS). *Methods*: Whereas previous literature has reported a significant association between smoking and mental health, identifying the causal pathway is difficult. To address the plausible reverse causality from mental health to smoking and omitted unobserved factors, we employ the method of instrumental variables (IV) by using state cigarette excise tax as an instrument for smoking. *Results*: Our findings show that smoking increases the number of days with poor mental health especially among individuals with more severe illness (more than 14 days in the past month). *Conclusions*: Our estimates suggest that smoking causes poor mental health and its effects are concentrated for measures that indicate more severe problems. Public health policies that aim to reduce smoking also may reduce poor mental health.**

***Key words*: smoking; mental health; cigarette excise tax**

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The adverse health effects of smoking are well documented.[1] Smoking has been biologically linked to chronic obstructive pulmonary disease (COPD), coronary heart disease, stroke, and lung cancer; moreover, smoking also is associated with self-reported poor general health, poor mental and physical health, and frequent activity limitations.[2-5] Whereas the overall smoking rate has been declining steadily in the United States (US), the rate among adults with mental disorders remains disproportionately high.[6] Previous studies have found that adults with mental health problems are more likely to smoke.[9-15] Among those with mental illness, about 36% were current smokers compared with 21% among adults with no mental illness.[7,8]

As this evidence shows, there is a well-documented association between smoking and mental health. However, whether this association is causal, the direction of causality is not yet known, because measuring the causal link between smoking and mental health is difficult for several reasons. First, poor mental and physical health could cause smoking through self-medication.[18-23] Nicotine increases levels of selective serotonin reuptake inhibitors (SSRIs) and dopamine, which stimulate positive reinforcing effects, increased energy, and reduced depression and anxiety.[18,19] A few clinical trials have presented evidence that nicotine reduces depressive symptoms and improves sleep among nonsmokers wearing nicotine patches.[20-23]

Second, smoking (nicotine) could cause poor mental health through neurotransmitter pathways.[11,24-26]

Although nicotine can act as an antidepressant, chronic use could lead to an increase in anxiety and depression following withdrawal.[24] Furthermore, because cigarette smoking contains over 7000 harmful chemicals, including 70 known cancer-causing compounds, smoking can adversely affect health. Besides cancer, smoking has long been associated with respiratory problems.[27,28] Poor physical health could lead to poor mental health because of the unpleasantness and activity-limiting aspects of being physically sick.

Finally, the association between smoking and health may not be completely causal because unobserved factors, such as certain personal characteristics, social environments and/or genes simultaneously impact both smoking and poor mental and physical health.[11,29-32] The common biological basis such as candidate genes for smoking that relate to dopamine pathways and nicotinic acetylcholine receptors (nAChRs) may increase serotonin release and lead to depression.[32]

In summary, the association between smoking and mental and physical health may be simultane-

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ous and bi-directional. Furthermore, there is non-random selection into smoking that is partly determined by mental and/or physical health; moreover, unobserved factors may affect both smoking and poor mental and physical health.[16] Our research addresses these problems, and in doing so, contributes significantly to the literature in this area. Specifically, we use an instrumental variables (IV) approach that exploits variation in smoking due to differences in state cigarette taxes to estimate the effect of smoking on mental health.

Data for the analysis come from the Behavioral Risk Factor Surveillance System (BRFSS) from 2000 to 2010. Findings from our analysis indicate that smoking is associated with poorer mental and physical health. Smokers have one-half of a standard deviation more days with poor mental health and one standard deviation more days with poor physical health than non-smokers. Most of the adverse effects of smoking are associated with an increase in the proportion of persons experiencing a large number of days (>14 in past month) in poor health.

METHODS

Data

Data for the analysis were drawn from the Behavioral Risk Factor Surveillance System (BRFSS), a telephone-based survey of self-reported health conditions and health-related risk behaviors among adults 18 years or older sponsored by US Centers for Disease Control and Prevention (CDC). The core questionnaire is administered in all states and Washington, DC. Each state has options to include additional questions to fit its interests.

We used data from years 2000 to 2010. The main reason we stopped at year 2010 is that in 2011, the BRFSS changed its method of statistical weighting significantly. These new methods potentially affect the prevalence estimates.[33] We excluded individuals with more than a high school diploma or GED, and older than 64 years because there are few smokers who have college degrees, so they are not particularly relevant. Similarly, there are relatively few smokers who are age 65 and older and they are long time smokers who are unlikely to respond to changes in tobacco taxes, which is the key for our research strategy.

According to the CDC, smoking rates were higher among US adults aged 25 and older who did not graduate from high school (22.9%) and those who had a high school diploma (21.7%) or GED (43%) compared with those with a college degree (7.9%).[34] The BRFSS confirms this; among adults aged 18 to 64, 39.5% who did not graduate from high school and 30.3% who had a high school diploma or GED were current smokers, compared with 23.8% who had attended some college and 10.9 % with a college degree. Finally, we also excluded individuals with missing demographic characteristics. The total sample is 863,856.

To estimate the effect of smoking on mental and physical health, our dependent variables were derived from the core questionnaire section called "healthy days." Specifically, we used the following questions:

1. Would you say that in general your health is excellent, very good, good, fair, or poor?

2. "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?"

3. "Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?"

4. "During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?"

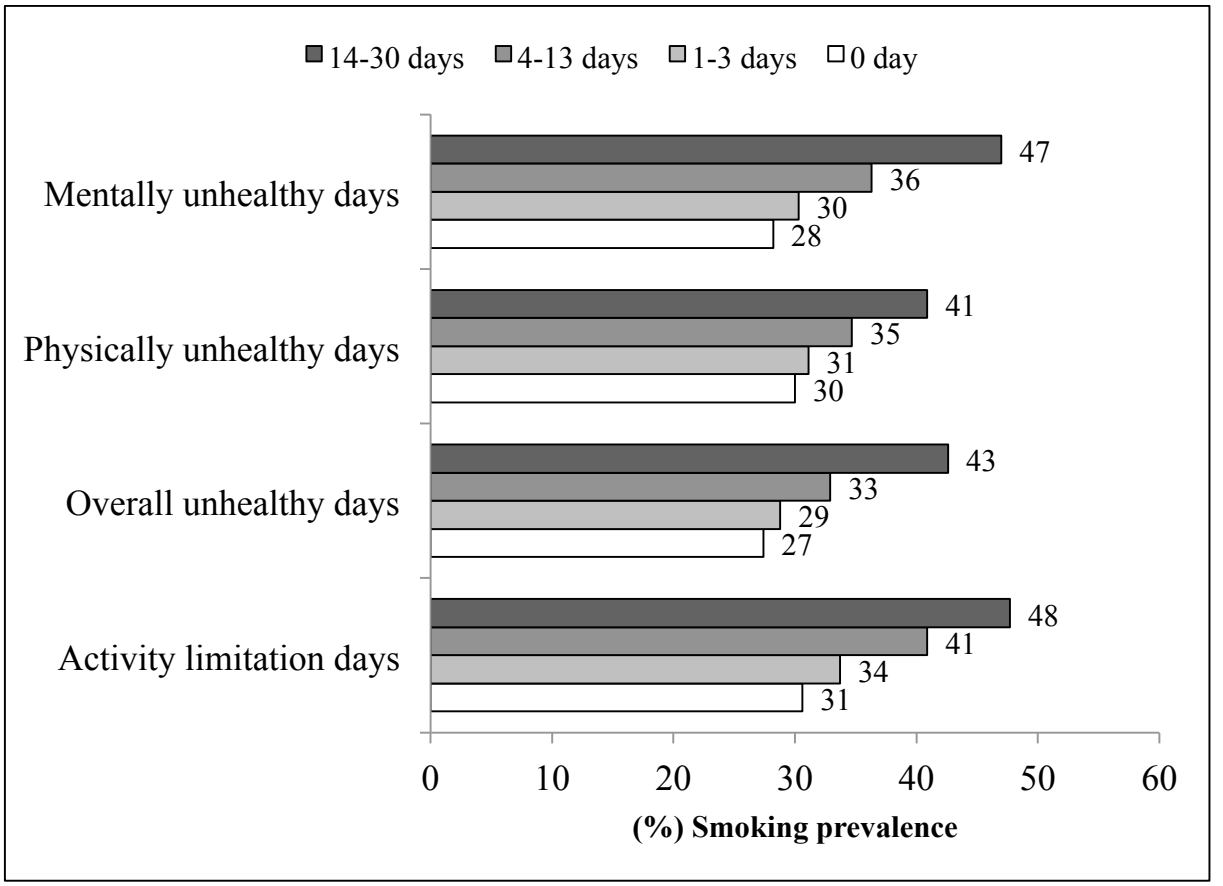
Note that questions 2, 3, and 4 were asked in all states and years, except in the year 2002, which they were parts of optional modules and only 21 states (AK, HI, ID, IL, IA, KS, KY, MN, MO, NJ, NM, NY, NC, OR, RI, SC, TX, UT, VA, WA, and WY) were asked these questions.

From the first question, we constructed a dichotomous indicator for fair/poor general health with value of 1 if a participant reported that his/her general health is fair or poor and 0 otherwise. Next, we measured mentally unhealthy days, physically unhealthy days, and activity limitation days due to poor physical and mental health by using questions 2-4, respectively. Each variable has values between 0 and 30. Notably, if a participants responded that their mental and physical health status was "not good" on "0 days," they were not asked the last question. These participants were assigned the value of 0 activity limitation days.

We also constructed an overall unhealthy days variable by combining mentally and physically unhealthy days (questions 2 and 3), with a maximum of 30 days.[35] For example, persons who reported 3 mentally unhealthy days and 5 physically unhealthy days were assigned a value of 8 unhealthy days and persons who reported 20 mentally unhealthy days and 30 physically unhealthy days were assigned the maximum of 30 unhealthy days.[36]

Furthermore, smoking may affect the severity of mental and physical health differently. As Figure 1 shows, smoking prevalence was positively correlated with all 4 health variables. For example, the rate of smoking among adults with 0 mentally unhealthy days was about 28%; it was 30% among those with 1-3 mentally unhealthy days and almost 50% among those with 14 or more mentally unhealthy days.

Figure 1
Smoking Prevalence by Mentally and Physically Unhealthy Days and Activity Limitation Days among Adults Aged 18 to 64



To assess whether smoking has effects at different points in the distribution of the number of days in poor mental and physical health, we constructed a set of dichotomous variables indicating the following: any distress (value 1 if ≥ 1 day; 0 otherwise), mild distress (value of 1 if ≥4 days; 0 otherwise), and frequent distress (value of 1 if ≥ 14 days; 0 otherwise). Most clinicians and clinical researchers also use the final category's cut-off as a benchmark for clinical depression and anxiety, as well as physical illness and activity limitation.[37-39]

We created a current smoking indicator with a value of 1 if a participant smoked at least 100 cigarettes in his/her lifetime and smoked cigarettes now, and 0 if a participant was a never smoker or a former smoker. We also included the following individual-level demographic characteristics: age fixed effect (18-64), sex, race/ethnicity (white, black, Hispanic, and other race), education (less than high school and high school), marital status (married, divorced, widowed, and never married), household income (<$10,000, $10-$19,999, $20-$34,999, $35-$49,999, $50-$74,999, and ≥ $75,000) and state of residence. We included sample weight as a covariate to control for non-random probability of being selected into the sample.[40]

Finally, we obtained information on state cigarette excise tax from *The Tax Burden on Tobacco*.[41] We adjusted cigarette tax based on 2010 dollars. We also constructed dummy variables reflecting tax by sex, education and marital status.

Table 1 presents unweighted descriptive statistics of outcomes and demographic variables by smoking status. We observed statistically significant differences between non-smokers and smokers for all outcomes and demographic characteristics. On average, smokers reported more mentally, physically, and overall unhealthy days and days with activity limitation than non-smokers. They were also more likely to report fair/poor general health than non-smokers. Smokers were younger, more likely to be men and white, and less likely to have a high school diploma and be married than non-smokers. The substantial differences between

smokers and non-smokers illustrated the likely confounding of associations between smoking and health, and underscored the value of our approach that addresses this problem.

Empirical Approach

Our interest was to obtain estimates of the associations between smoking and mental and physical health that can plausibly be interpreted as causal. We used the following model specification:

$$(1) \quad \Upsilon_{ijt} = \beta_0 + \beta_1 \text{SMOKE}_{ijt} + \beta_2 \chi_{ijt} + \delta_j + \Upsilon_t + \varepsilon_{ijt}$$

i = 1… N (persons)
j = 1… j (states)
t = 2000… 2010 (years)

In equation (1), Y represents days in poor mental or physical health of person i in state j and year t. Health (Y) depends on current smoking ($SMOKE_{ijt}$); a set of demographic characteristics (X_{ijt}) that includes age, sex, race, marital status, and education; state fixed effects (δ_j); year fixed effects (Υ_t); and the error term (ε_{ijt}). For outcomes measured as number of days, regression estimates were obtained using Poisson methods. For dichotomous outcomes, all regression estimates were obtained using OLS.

Ideally, we would like to interpret estimates of the association between smoking and mental or physical health, β_1, as causal. However, the primary concerns to a causal interpretation are from the reverse causality from mental or physical health to smoking and the omitted factors that are correlated with mental or physical health and smoking.

To address these empirical problems, we used an instrument variable (IV) approach. The IV method uses variation in smoking that is plausibly exogenous. In our case, we exploit variation in smoking caused by state tobacco taxes. As is well documented, smokers are sensitive to increases in cigarette tax especially among men, lower-educated, and never-married adults.[42-47] Thus, we also interacted cigarette excise tax with men, lower-educated adults, and never-married adults to create additional variation in the smoking that we used to obtain estimates of the effect of smoking.

The key assumption is that, conditional on smoking (and state and year effects, and other covariates) state cigarette taxes are uncorrelated with health. This is the exclusion restriction of the instrumental variables approach. Basically, the IV approach assumes that there are no unmeasured, state-specific, time-varying factors that are correlated with both state cigarette taxes and people's health. We provide evidence for this assumption below.

For the Poisson models, which we used for the number of days and measures of health, we employed a 2-stage residual inclusion (2SRI) instrumental variables approach as Wooldridge suggests.[48,49] In the first stage, we estimated the effects of cigarette excise tax on current smoking by using an ordinary least squares (OLS) method to obtain the predicted residual and residual squared. We then include the residual and squared residual in our regression model for health.

The first stage regression used to predict smoking is:

$$(2) \quad \text{SMOKE}_{ijt} = \alpha_0 + \alpha_1 \text{Tax}_{jt} + \alpha_2(\text{Tax}_{jt} \times \text{Male}_i) + \alpha_3(\text{Tax}_{ji} \times \text{LSHS}_i) + \alpha_4(\text{Tax}_{jt} \times \text{NeverMarried}_i) + \alpha 6 \chi_{ijt} + \delta_j + \Upsilon_t + \mu_{ijt}$$

I = 1,…,N (persons)
j = 1,…,j (states)
t = 2000, …, 2010 (years)

In equation (2), the dependent variable is equal to 1 if a participant is a current smoker and 0 otherwise. Covariates include state cigarette excise tax in 2010 dollars (*Tax*), an interaction between cigarette tax and men, an interaction between cigarette tax and less than a high school education (LSHS), and an interaction between tax and being never-married; X is a vector of demographic variables as in equation (1); δ_j and Υ_t are state and year fixed effects; and is an error term. The specification of equation (2) allows the effect of state taxes to differ by demographic characteristics (sex, education, and marital status).

The second stage is estimated as follow:

$$(3) \quad \Upsilon_{ijt} = \beta_0 + \beta_1 \text{SMOKE}_{ijt} + \beta_2 \chi_{ijt} + \delta_j + \Upsilon_t + \beta_3 \widehat{\text{Res}} + \beta_4 \widehat{\text{Res}^2} + \varepsilon_{ijt}$$

Equation (3) is similar to equation (1) except we include the predicted residual and residual squared in the Poisson regression model. Because this approach is non-standard IV, we bootstrap standard errors by performing 500 replications of the 2SRI estimate procedure.

For dichotomous indicators of health, we use a standard *2-stage least square (2SLS)* procedure. The first stage estimate is the same as in equation (2). For the second stage, we obtained predicted values of current smoking from the first stage and then use those predicted values in the outcome equation. Specifically, we estimate the following model:

$$(4) \quad \text{Y}_{ijt} = \beta_0 + \beta_1 \widehat{\text{SMOKE}}_{ijt} + \beta_2 \chi_{ijt} + \delta_j + \Upsilon_t + \varepsilon_{ijt}$$

I = 1,…,N (persons)
j = 1,…,j (states)
t = 2000, …, 2010 (years)

RESULTS

The Effect of Smoking on Mental Health

Tables 2 and 3 present estimates of the effects of smoking on mental and physical health measures. The first results we present are estimates of equation (2), which represent the first stage of the IV procedure. Overall estimates indicate that a one dollar increase in cigarette excise tax will decrease the probability of being a smoker by 2.1

Table 1
Descriptive Statistics

	Non-smokers		Smokers		Total	
	Mean	SD	Mean	SD	Mean	SD
Dependent variables						
Fair/poor general health	0.202	0.402	0.271	0.444	0.224	0.417
Mentally unhealthy days	3.801	8.077	6.582	10.432	4.697	8.999
Physically unhealthy days	4.127	8.598	5.748	10.037	4.650	9.119
Overall unhealthy days	6.747	10.450	10.008	12.125	7.798	11.123
Activity limitation days due to poor physical or mental health	1.567	5.756	2.883	7.746	1.991	6.494
Frequent mental distress (≥ 14 days)	0.119	0.324	0.222	0.416	0.152	0.359
Frequent physical distress (≥ 14 days)	0.131	0.337	0.190	0.392	0.150	0.357
Frequent unhealthy days (≥ 14 days)	0.210	0.408	0.328	0.470	0.248	0.432
Frequent activity limitation days (≥ 14 days)	0.053	0.224	0.102	0.302	0.069	0.253
Independent variables						
Current smoking	N/A	N/A	N/A		0.322	0.467
Instrumental variables						
State cigarette excise tax ($/pack)	0.971	0.703	0.925	0.690	0.956	0.700
Demographic variables						
Age	44.91	13.07	42.93	12.40	44.27	12.89
Men	0.395	0.489	0.436	0.496	0.409	0.492
Race/Ethnicity						
White	0.692	0.462	0.754	0.431	0.712	0.453
Black	0.112	0.315	0.100	0.300	0.108	0.311
Hispanic	0.142	0.349	0.076	0.265	0.121	0.326
Other races	0.054	0.227	0.070	0.256	0.059	0.237
Education						
High school degree	0.809	0.393	0.738	0.440	0.786	0.410
Marital Status						
Married	0.621	0.485	0.495	0.500	0.580	0.494
Divorced	0.167	0.373	0.262	0.440	0.198	0.398
Widowed	0.045	0.208	0.050	0.217	0.047	0.211
Never married	0.167	0.373	0.194	0.395	0.176	0.381
Household income						
Less than $10,000	0.064	0.245	0.099	0.299	0.076	0.264
$10,000 to $19,999	0.147	0.354	0.200	0.400	0.164	0.370
$20,000 to $34,999	0.244	0.430	0.274	0.446	0.254	0.435
$35,000 to $49,999	0.160	0.366	0.144	0.352	0.155	0.362
$50,000 to $74,999	0.136	0.342	0.101	0.302	0.125	0.330
$75,000 or More	0.116	0.321	0.069	0.254	0.101	0.302
Missing income	0.133	0.340	0.112	0.315	0.126	0.332
Number of observations	585,355		278,501		863,856	

Note.
The means differences between non-smokers and smokers are statistically significant for all variables.

Table 2
Estimates of the Effect of Current Smoking on Mentally and Physically Unhealthy Days

	Current Smoking	Mentally Unhealthy Days			Physically Unhealthy Days		
	OLS	OLS	Poisson	IV	OLS	Poisson	IV
Current smoking		2.051***	0.395***	0.925*	1.111***	0.223***	2.140***
		(0.028)	(0.005)	(0.367)	(0.025)	(0.004)	(0.362)
			[1.857]	[4.343]		[1.039]	[9.949]
Residual				-0.599			-1.944***
				(0.367)			(0.362)
				[-2.815]			[-9.039]
Residual squared				0.270***			0.101***
				(0.017)			(0.018)
				[1.266]			[0.468]
Instruments							
Current Cigarette Tax ($/pack)	-0.021***						
	(0.003)						
Current Tax × men	-0.000						
	(0.003)						
Current Tax × LSHS	0.071***						
	(0.003)						
Current Tax × Never Married	0.006*						
	(0.002)						
F-statistic of Test of Joint Significance of All Tax Variables (p-value)	23.89*** (0.000)						
Mean	0.322	4.697			4.650		
(standard deviation)	(0.485)	(9.00)			(9.119)		
Observations	863,856	863,856	863,856	863,856	863,856	863,856	863,856

*** p < .05, ** p < .01, *** p < .001**

Note.
LSHS is defined as less than high school.
The sample consists of adults 18 to 64 years of age with a high school degree or less. All regression models include state and year fixed effects, dummy variables for age, men, race/ethnicity, high school degree, marital status, family income categories, and final sample weight. Bootstrapped standard errors reported in parentheses and are constructed allowing for non-independence within state-year groups. Marginal effects are reported in brackets.

Table 3
Estimates of the Effect of Current Smoking on Overall Unhealthy and Activity Limitation Days

	Current Smoking	Overall Unhealthy Days			Activity Limitation Days		
	OLS	OLS	Poisson	IV	OLS	Poisson	IV
Current smoking		2.385***	0.284***	1.306***	0.868***	0.384***	2.509***
		(0.032)	(0.003)	(0.270)	(0.020)	(0.008)	(0.608)
			[2.215]	[10.188]		[0.764]	[4.996]
Residual				-1.066**			-2.207**
				(0.270)			(0.608)
				[-8.316]			[-4.395]
Residual squared				0.161***			0.352***
				(0.013)			(0.029)
				[1.254]			[0.700]
Instruments							
Current Cigarette Tax ($/pack)	-0.021***						
	(0.003)						
Current Tax × men	-0.000						
	(0.003)						
Current Tax × LSHS	0.071***						
	(0.003)						
Current Tax × Never Married	0.006*						
	(0.002)						
F-statistic of Test of Joint Significance of All Tax Variables (p-value)	23.89*** (0.000)						
Mean	0.322	7.798			1.991		
(standard deviation)	(0.485)	(11.123)			(6.494)		
Observations	863,856	863,856	863,856	863,856	863,856	863,856	863,856

*** p < .05, ** p < .01, *** p < .001**

Note.
LSHS is defined as less than high school.
The sample consists of adults 18 to 64 years of age with a high school degree or less. All regression models include state and year fixed effects, dummy variables for age, men, race/ethnicity, high school degree, marital status, family income categories, and final sample weight. Bootstrapped standard errors reported in parentheses and are constructed allowing for non-independence within state-year groups. Marginal effects are reported in brackets.

Table 4
Estimates of the Effect of Current Smoking on Mentally and Physically Unhealthy Days

	Any Distress (≥ 1 day)		Mild Distress (≥ 4 days)		Frequent Distress (≥ 14 days)	
	OLS	IV	OLS	IV	OLS	IV
Panel A: Mentally Unhealthy Days						
Current smoking	0.083***	0.163	0.092***	0.261*	0.077***	0.246**
	(0.001)	(0.151)	(0.001)	(0.109)	(0.001)	(0.076)
Mean	0.377		0.265		0.152	
(standard deviation)	(0.485)		(0.442)		(0.359)	
Panel B: Physically Unhealthy Days						
Current smoking	0.042***	0.283*	0.050***	0.484***	0.041***	0.483***
	(0.001)	(0.143)	(0.001)	(0.115)	(0.001)	(0.089)
Mean	0.379		0.250		0.150	
(standard deviation)	(0.485)		(0.433)		(0.367)	
Panel C: Overall Unhealthy Days						
Current smoking	0.074***	0.214	0.091***	0.419**	0.087***	0.443***
	(0.001)	(0.165)	(0.001)	(0.143)	(0.001)	(0.098)
Mean	0.514		0.405		0.249	
(standard deviation)	(0.498)		(0.491)		(0.432)	
Panel : Activity Limitation Days						
Current smoking	0.043***	0.282**	0.042***	0.312***	0.032***	0.272***
	(0.001)	(0.097)	(0.001)	(0.081)	(0.001)	(0.070)
Mean	0.134		0.104		0.069	
(standard deviation)	(0.485)		(0.305)		(0.253)	
Observations	863,856	863,856	863,856	863,856	863,856	863,856

*** p < 0.05, ** p < 0.01, *** p < 0.001**

Note.
The sample consists of adults 18 to 64 years of age with a high school degree or less. All regression models include state and year fixed effects, dummy variables for age, men, race/ethnicity, high school degree, marital status, family income categories, and final sample weight.

percentage points (about 6.5% of the mean). The coefficient on men by tax interaction is not statistically significant whereas the coefficient on less than a high school education is positive and significant, indicating that adults with lower education are less responsive to a cigarette tax than those with a high school diploma. The interaction between tax and being never-married is positive and marginally significant. The strength of the associations between smoking and cigarette tax are strong. The joint F-test on all tax instruments is (F = 23.89).

For each outcome, we show estimates from simple Poisson regressions and IV Poisson models. For

all outcomes, all estimates are positive and statistically significant. Estimates from simple Poisson models suggest that smoking is associated with between a 22% (eg, Poisson estimate of 0.223) and a 40% (eg, Poisson estimate 0.395) increase in the number of unhealthy and activity-limited days. We calculate the marginal effects (effects on number of days and not percentage effects) and present them in brackets. Smokers are predicted to have 1.86 more mentally unhealthy days, 1.04 more physically unhealthy days, 2.21 more overall unhealthy days, and 0.76 more activity-limited days than non-smokers.

Estimates from the IV Poisson models are considerably larger and indicate that smoking is associated with an increase in unhealthy days of about 90% to 250%. It is important to note that these estimates are relative to the mean, which may be misleading in terms of assessing the plausibility of the estimates. Standard deviations of the number of days in poor health are large –between 6 and 11 days – and much larger than the means. Consider the effect of smoking on overall unhealthy days in Table 3 obtained by the IV Poisson method. It is 1.31, which indicates a 131% increase from the mean of 7.8. The marginal effect in brackets indicates that this effect represents about 10 days, which represents about one standard deviation. So smoking increases the overall number of unhealthy days by one standard deviation according to the Poisson IV estimates – and this is a plausible effect.

In Appendix 1, we explore whether our results are different when we use different instruments for smoking. Specifically, we estimated the similar models to those in Table 2 but using lagged cigarette taxes, and current and lagged cigarette taxes as instruments. Results from these models are similar to those in Tables 2 and 3. In addition, we also examine the effects of daily smoking on health as shown in Appendix 2 and Appendix 3. The results are also similar to those in Table 2.

As noted previously, smoking may affect health at different points in the distribution of unhealthy days, for example, by primarily causing an increase in the proportion of people with severe health problems. We investigated this hypothesis by allowing the effects of smoking to differ by different thresholds of unhealthy days. Table 4 presents OLS and standard 2SLS (IV) estimates. For each type of distress (any, mild, and frequent), we presented results for OLS and IV estimates.

Consider estimates in Panel A where we measure the effects of smoking on differences in mentally unhealthy days. Estimates indicate that smoking is significantly associated with 14 or more days of poor mental health, but note that the estimate is about the same as the indicator for 4 or more days and 14 or more days. This suggests that most of the change in mental health due to smoking is from large increases in the number of mentally unhealthy days and not by small increases among many smokers. The increase in the probability of frequent distress from smoking is 24.6 percentage points, which is over a 100% increase.

We show estimates of the association between smoking and physically unhealthy days (Panel B), and combined unhealthy days (Panel C). In each case the magnitude of smoking coefficient substantially increases – almost doubles – from the lowest threshold to the highest threshold.

Finally, Panel D presents estimates for smoking and activity limitation days. The coefficients indicate that smoking affects the probability of any, mild and frequent distress similarly (28.2, 31.2, and 27.2 %, respectively). Again, the similarity of estimates suggests that most of the effect of smoking is to cause some smokers to have substantially poorer mental and physical health rather than a small increase for most smokers.

Table 5
The Effects of Smoking on Flu Shot

	OLS	IV
Current smoking	-0.043***	0.119
	(0.001)	(0.093)
Mean	0.271	
(standard deviation)	(0.445)	
Observations	815,897	815,897

*** p < .05, ** p < .01, *** p < .001**

Note.
The sample consists of adults 18 to 64 of age with a high school degree or less. All regression models include state and year fixed effects, dummy variables for age, men, race/ethnicity, high school degree, marital status, family income categories, and final sample weight.

Placebo Analysis

To test the validity of the IV research design, we created a placebo test in which we analyzed the association between having a flu shot during the past year and smoking. We do not expect smoking to affect the probability of having a flu shot, although if smoking adversely affects health, it may cause those who are sicker to get a flu shot. We used the same IV approach for this outcome. Estimates are in Table 5. The OLS estimated coefficient in column (2) is positive and statistically significant; however, the coefficient on smoking after we adjust for tax is statistically non-significant. The fact that the IV approach eliminated the finding that smoking is associated with the probability of obtaining a flu shot is good evidence of the efficacy of the IV approach. The correlation between obtaining a flu shot and smoking is likely due to omitted factors, which the IV approach is intended to address.

DISCUSSION

The disproportionately high smoking prevalence in the population with mental health problems has raised a concern that this population is at increased risk for smoking-related illness. Previous studies have documented the associations between smoking and mental and physical health. However, most of these studies did not address whether these associations represented a causal relationship. In this paper, we address the causality issue by using a plausible exogenous source of smoking – state cigarette excise tax.

Our estimates suggest that smoking is a cause of poor mental health. We also showed that most of this association is driven by smoking causing an increase in severe problems (≥14 mentally and physically unhealthy days), which the CDC believes can be associated with specific health conditions. Furthermore, the marginal effects indicate that smoking increased mentally unhealthy days by about one-half of a standard deviation, increased physically and overall unhealthy days by about one standard deviation, and increased days with activity limitation by about three-fourths of a standard deviation. These estimates are consistent with the estimates of the association between smoking and fair/poor health status (results not shown). We found that the probability of having fair/poor health status is about 59% higher among smokers compared with non-smokers. These estimates are consistent with previous evidence that smoking has a negative impact on physical health.

There are a couple explanations for the causal effects we found. The most obvious explanation is that smoking has been associated with the number of chronic diseases such as chronic obstructive pulmonary disease, ischemic heart disease, and other chronic illnesses,[1] and therefore, smoking may cause poor physical health in general. Next, the plausible explanation is that nicotine may induce poor mental health through changes in neurotransmitter pathway.

Limitations

This study has some limitations. First, smoking status, mental health, and physical health were obtained based on self-report from the BRFSS. We cannot validate either smoking, mental health, or physical health status. Second, information on health was limited to general mental and physical health and may not applicable to specific diseases. In addition, whereas we believe that the instrumental variables approach we employ is plausible and that estimates from it may reasonably be interpreted as causal, we acknowledge that the approach is not definitive.

One weakness of the approach is the limited variation in tobacco use that results from differences in tobacco control policies across states and time. This leads to some imprecise estimates. A second weakness is the possibility that tobacco control policies may be correlated with other factors that influence health directly, and not only through smoking behavior. Third, the estimates we obtain may not generalize to the full population of smokers because our effect is estimated from those who were induced to alter their smoking by state tobacco control policies.

Overall, our estimates indicate that smoking causes poor mental and physical health and its effects were concentrated for measures that indicate severe problems. Our conclusion suggests that public health policies that aim to reduce smoking will have a spill-over effect to poor mental and physical health. Whereas the latter effect is well documented, the adverse effect on mental health has not been previously reported. Further research is necessary to determine the impact of smoking on more specific mental illnesses. Such an understanding will help to develop effective interventions to reduce both smoking and poor mental health.

Human Subject Statement

This study does not require institutional review board approval because we used secondary data from Behavioral Risk Factor Surveillance System through which researchers cannot identify any particular participant.

Conflict of Interest Statement

Drs. Plurphanswat and Rodu are supported by unrestricted grants from tobacco manufacturers (Swedish Match AB, Reynolds American Inc. Services Company, Altria Client Services and British American Tobacco) to the University of Louisville, and by the Kentucky Research Challenge Trust Fund. The terms of the grants assure that the sponsors are unaware of this study, and thus, had no scientific input or other influence with respect to its design, analysis, interpretation or preparation of the manuscript. Neither of the authors has any financial or other personal relationship with regard to the sponsors.

References

1. US Department of Health and Human Services (USDHHS). The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General. Atlanta, GA: USDHHS, US Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2014.
2. Wilson D, Parsons J, Wakefield M. The health-related quality-of-life of never smokers, ex-smokers, and light, moderate, and heavy smokers. *Prev Med.* 1999;29(3):139-144.
3. Strine TW, Okoro CA, Chapman DP, et al. Health-related quality of life and health risk behaviors among smokers. *Am J Prev Med.* 2005;28(2):182-187.
4. Mody RR, Smith MJ. Smoking status and health-related quality of life: findings from the 2001 Behavioral Risk Factor Surveillance System data. *Am J Health Promot.* 2006;20(4):251-258.
5. McClave AK, Dube SR, Strine TW, Mokdad AH. Associations between health-related quality of life and smoking status among a large sample of U.S. adults. *Prev Med.* 2009;48(2):173-179.
6. Lawrence D, Williams JM. Trends in smoking rates by

level of psychological distress—time series analysis of US National Health Interview Survey data 1997–2014. *Nicotine Tob Res*. 2016;18(6):1463-1470.
7. US Centers for Disease Control and Prevention. Vital signs: current cigarette smoking among adults aged ≥18 years with mental illness – United States, 2009–2011. *MMWR. Morb Mortal Wkly Rep*. 2013;62:81-87.
8. Pratt LA, Brody DJ. *Depression and Smoking in the U.S. Household Population Aged 20 and Over, 2005–2008*. NCHS data brief, no 34. Hyattsville, MD: National Center for Health Statistics; 2010.
9. Hughes JR, Hatsukami DK, Mitchell JE, Dahlgren LA. Prevalence of smoking among psychiatric outpatients. *Am J Psychiatry*. 1986;143(8):993-997.
10. Anda RF, Williamson DF, Escobedo LG, et al. Depression and the dynamic of smoking: a national perspective. *JAMA*. 1990;264(12):1541-1545.
11. Glassman AH, Helzer JE, Covey LS, et al. Smoking, smoking cessation, and major depression. *JAMA*. 1990;264(12):1546-1549.
12. Breslau N, Peterson EL, Schultz LR, et al. Major depression and stages of smoking: a longitudinal investigation. *Arch Gen Psychiatry*.1998;55(2):161-166.
13. Lasser KJ, Boyd W, Woolhandler S, et al. Smoking and mental illness: a population-based prevalence study. *JAMA*. 2000;284(20):2606-2610.
14. Lawrence D, Mitrou F, Zubrick SR. Smoking and mental illness: results from population surveys in Australia and the United States. *BMC Public Health*. 2009;9:285.
15. McManus S, Meltzer H, Campion J. Cigarette smoking and mental health in England: data from the adult psychiatric morbidity survey 2007. Available at: http://www.natcen.ac.uk/media/21994/smoking-mental-health.pdf. Accessed January 31, 2017.
16. Adda J, Lechene V. Health selection and the effects of smoking on mortality. *Scand J Economics*. 2013;115(3):902-931.
17. Szatkowski L, McNeill A. Diverging trends in smoking behaviors according to mental health status. *Nicotine Tob Res*. 2015;17(3):356-360.
18. Watkins SS, Koob GF, Markou A. Neural mechanisms underlying nicotine addiction: acute positive reinforcement and withdrawal. *Nicotine Tob Res*. 2000;2(1):19-37.
19. Laje RP, Berman JA, Glassman AH. Depression and nicotine: preclinical and clinical evidence for common mechanisms. *Curr Psychiatry Rep*. 2001;3(6):470-474.
20. Salin-Pascual RJ, De La Fuente JR, Galicia-Polo L, Drucker-Colin R. Effects of transdermal nicotine on mood and sleep in nonsmoking major depressed patients. *Psychopharmacology (Berl)*. 1995;121(4):476-479.
21. Salin-Pascual RJ, Drucker-Colin R. A novel effect of nicotine on mood and sleep in major depression. *Neuroreport*. 1998;9(1):57-60.
22. McClernon FJ, Hiott FB, Westman EC, et al. Transdermal nicotine attenuates depression symptoms in nonsmokers: a double-blind, placebo-controlled trial. *Psychopharmacology (Berl)*. 2006;189(1):125-133.
23. Cox LS, Patten CA, Krahn LE, et al. The effect of nicotine patch therapy on depression in nonsmokers: a preliminary study. *J Addict Dis*. 2003;22(4):75-85.
24. Picciotto MR, Brunzell DH, Caldarone BJ. Effects of nicotine and nicotinic receptors on anxiety and depression. *Neuroreport*. 2002;13(9):1097-1106.
25. Boden JM, Fergusson DM, Horwood LH. Cigarette smoking and depression: tests of causal linkages using a longitudinal birth cohort. *Br J Psychiatry*.2010;196(6):440-446.
26. Goodman E, Capitman J. Depressive symptoms and cigarette smoking among teens. *Pediatrics*. 2000;106(4):748-755.
27. US Department of Health and Human Services (USDHHS). *How Tobacco Smoke Causes Disease: The Biology and Behavioral Basis for Smoking-Attributable Disease: A Report of the Surgeon General*. Atlanta, GA: USDHHS, US Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2010.
28. Arday DR, Giovino GA, Schulman J, et al. Cigarette smoking and self-reported health problems among U.S. high school seniors, 1982–1989. *Am J Health Promot*. 1995;10(2):111-116.
29. Hughes JR. Clonidine, depression, and smoking cessation. *JAMA*. 1988;259(19):2901-2902.
30. Kendler KS, Neale MC, MacLean CJ, et al. Smoking and major depression: a causal analysis. *Arch Gen Psychiatry*.1993;50(1):36-43.
31. Quattrocki E, Baird A, Yurgelun-Todd D. Biological aspects of the link between smoking and depression. *Harvard Rev Psychiatry*. 2000;8(3):99-110.
32. Tsuang MT, Francis T, Minor K, et al. Genetics of smoking and depression. *Hum Genet*. 2012;131(6):905-915.
33. Pierannunzi C, Town M, Garvin W, et al. Methodologic changes in the Behavioral Risk Factor Surveillance System in 2011 and potential effects on prevalence estimates. *MMWR*. 2012;61(22):410-413.
34. Jamal A, Homa DM, O'Connor E, et al. Current cigarette smoking among adults – United States, 2005-2014. *MMWR Morb Mortal Wkly Rep*. 2015;64(44):1233-1240.
35. US Centers for Disease Control and Prevention. Health-related quality of life (HRQOL) – methods and measures. Available at: http://www.cdc.gov/hrqol/methods.htm. Accessed January 31, 2017.
36. Moriarty DG, Zack MM, Kobau R. The Centers for Disease Control and Prevention's healthy days measures – population tracking of perceived physical and mental health over time. *Health Qual Life Outcomes*. 2003;1:1-8.
37. Zahran HS, Kobau R, Moriarty DG, et al. Self-reported frequent mental distress among adults – United States, 1993-1996. *MMWR Morb Mortal Wkly Rep*. 1998;47(16):325-331.
38. Zahran HS, Kobau R, Moriarty DG, et al. Self-reported frequent mental distress among adults – United States, 1993-2001. *MMWR Morb Mortal Wkly Rep*. 2004;53(41):963-966.
39. Jiang Y, Hesser JE. Patterns of health-related quality of life and patterns associated with health risks among Rhode Island adults. *Health Qual Life Outcomes*. 2008;6:49.
40. Korn EL, Graubard BI. *Analysis of Health Surveys*. New York, NY: Wiley; 1999.
41. Orzechowski W, Walker RC. The *Tax Burden on Tobacco: Historical Compilation*. Vol. 47. Arlington, VA: Orzechowski and Walker; 2014.
42. Evans WN, Farrelly MC. The compensating behavior of smokers: taxes, tar and nicotine. *Rand J Econ*. 1998;29(3):578-595.
43. Keeler TE, Hu T, Barnett PG, Manning WG. Taxation, regulation, and addiction: a demand function from cigarettes based on time-series evidence. *J Health Econ*. 1993;21(1):1-18.
44. Chaloupka FJ, Warner KE. The economics of smoking. In Culyer AJ, Newhouse JP, eds. *Handbook of Health Economics. Volume 1B*. Amsterdam, The Netherlands: Elsevier; 2000:1539-1627.
45. Stehr M. The effects of cigarette taxes on smoking among men and women. *Health Econ*. 2007;16(12):1333-1343.
46. DeCicca P, McLeod L. Cigarette taxes and older adult smoking: evidence from recent large tax increases. *J Health Econ*. 2008;27(4):918-929.
47. Callison K, Kaestner R. Do higher tobacco taxes reduce adult smoking? New evidence of the effect of recent cigarette tax increases on adult smoking. *Econ Inq*. 2014;52(1):155-172.
48. Wooldridge JM. A quasi-likelihood methods for count

data. In Pesaran MH, Schmidt P, eds. *Handbook of Applied Econometrics. Volume II: Microeconometrics*. Oxford, UK: Blackwell; 1997:352-406.

49. Wooldridge JM. *Econometric Analysis of Cross Sectional and Panel Data*. Cambridge, MA: MIT Press; 2002.

Appendix 1
The Effects of Smoking on Mentally and Physically Unhealthy Days Using Lagged Cigarette Tax and Current and Lagged Cigarette Tax as Instrumental Variables

	Instruments: Lagged Cigarette Tax				Instruments: Current and Lagged Cigarette Tax			
	Mentally Unhealthy Days	Physically Unhealthy Days	Overall Unhealthy Days	Activity Limitation Days	Mentally Unhealthy Days	Physically Unhealthy Days	Overall Unhealthy Days	Activity Limitation Days
Current smoking prevalence	1.496***	2.488***	1.646***	3.475***	1.187**	2.308***	1.474***	2.941***
	(0.373)	(0.369)	(0.282)	(0.604)	(0.372)	(0.359)	(0.275)	(0.619)
	[7.028]	[11.567]	[12.832]	[6.920]	[5.575]	[10.730]	[11.50]	[5.857]
Residual	-1.171**	-2.292***	-1.406***	-3.174***	-0.862*	-2.112***	-1.235***	-2.640***
	(0.373)	(0.399)	(0.282)	(0.604)	(0.371)	(0.359)	(0.275)	(0.619)
	[-5.502]	[-10.658]	[-10.962]	[-6.319]	[-4.048]	[-9.820]	[-9.627]	[-5.257]
Residual squared	0.270***	0.102***	0.161***	0.352***	0.270***	0.101***	0.161***	0.352***
	(0.017)	(0.018)	(0.013)	(0.029)	(0.017)	(0.018)	(0.013)	(0.029)
	[1.267]	[0.472]	[1.258]	[0.702]	[1.267]	[0.471]	[1.257]	[0.701]
Observations	863,856	863,856	863,856	863,856	863,856	863,856	863,856	863,856

*** p < .05, ** p < .01, *** p < .001**

Note.
The sample consists of adults 18 to 64 years of age with a high school degree or less. All regression models include state and year fixed effects, dummy variables for age, men, race/ethnicity, high school degree, marital status, family income categories, and final sample weight. Table 1 shows categories for all dummy variables. Bootstrapped standard errors reported in parentheses and are constructed allowing for non-independence within state-year groups. Marginal effects are reported in brackets.

Appendix 2
Estimates of the Effect of Daily Smokers on Mentally and Physically Unhealthy Days

	Mentally Unhealthy Days			Physically Unhealthy Days		
	OLS	Poisson	IV	OLS	Poisson	IV
Daily smoking	2.021***	0.372***	1.023*	0.935***	0.186***	2.374***
	(0.029)	(0.005)	(0.441)	(0.027)	(0.005)	(0.430)
		[1.746]	[4.807]		[0.864]	[11.037]
Residual			-0.810			-2.270***
			(0.441)			(0.430)
			[-3.805]			[-10.557]
Residual squared			0.417***			0.212***
			(0.019)			(0.021)
			[1.957]			[0.987]
Observations	863,856	863,856	863,856	863,856	863,856	863,856

*** p < .05, ** p < .01, *** p < .001**

Note.
The sample consists of adults 18 to 64 years of age with a high school degree or less. All regression models include state and year fixed effects, dummy variables for age, men, race/ethnicity, high school degree, marital status, family income categories, and final sample weight. Table 1 shows categories for all dummy variables. Bootstrapped standard errors reported in parentheses and are constructed allowing for non-independence within state-year groups. Marginal effects are reported in brackets.

Appendix 3
Estimates of the Effect of Daily Smokers on Overall Unhealthy and Activity Limitation Days

	Overall Unhealthy Days			Activity Limitation Days		
	OLS	Poisson	IV	OLS	Poisson	IV
Daily smoking	0.693***	0.295***	1.494***	2.263***	0.262***	2.560**
	(0.022)	(0.009)	(0.326)	(0.034)	(0.004)	(0.729)
		[0.587]	[11.649]		[2.041]	[5.098]
Residual			-1.340***			-2.438**
			(0.326)			(0.729)
			[-10.45]			[-4.855]
Residual squared			0.276***			0.487***
			(0.015)			(0.033)
			[2.154]			[0.970]
Observations				863,856	863,856	863,856

*** p < .05, ** p < .01, *** p < .001**

Note.
The sample consists of adults 18 to 64 years of age with a high school degree or less. All regression models include state and year fixed effects, dummy variables for age, men, race/ethnicity, high school degree, marital status, family income categories, and final sample weight. Table 1 shows categories for all dummy variables. Bootstrapped standard errors reported in parentheses and are constructed allowing for non-independence within state-year groups. Marginal effects are reported in brackets.