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FULL ARTICLE

State cigarette taxes and health expenditures: Evidence from dynamic spatial lag panel models

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Abstract

This study explores the relationship between state cigarette taxes and state expenditures on health and hospitals. We address two major sources of endogeneity from (i) the relationship between tax rates and expenditure decisions and (ii) spatial dependence in expenditure policies by using tobacco production as an instrument for cigarette tax rates and through a dynamic spatial Durbin model. We estimate the cigarette tax rate expenditure elasticity to be 0.03 (SR) and 0.87 (LR) for state health spending and 0.05 (SR) and 0.79 (LR) for state hospital spending. Increases in cigarette taxes did not reduce state spending on health over this period.

KEYWORDS

cigarette tax, dynamic spatial Durbin model, government health spending

1 | INTRODUCTION

Federal, state and local governments spend substantial sums of money on health care programs and hospitals each year. According to National Center for Health Statistics (2016), personal health care expenditures in the United States totalled $2.6 trillion in 2014. Nearly 40% of these expenditures were paid by Medicare and Medicaid, the two largest public health care programmes, and roughly 40% of Medicaid expenditures are borne by state and local governments.

The Congressional Budget Office (2012) recently estimated that roughly 7% of the nation's total annual health care spending is attributable to smoking. Cigarette taxes have been used in an attempt to relieve some of this public sector fiscal pressure and represent a revenue source for funding health care programmes (Grossman, Sindelar, Mullahy, & Anderson, 1993). The Tax Policy Center reports that state and local tobacco tax revenues were over $18 billion in 2013.[1]

Cigarette taxes also discourage smoking (Callison & Kaestner, 2014b; DeCicca & McLeod, 2008; MacLean, Kessler, & Kenkel, 2015; Maclean, Webber, & Marti, 2014; Pesko, Tauras, Huang, & Chaloupka, 2016). Many

[1]State & Local Government Finance Data Query System, http://slfdqs.taxpolicycenter.org/pages.cfm, accessed June 27, 2016.

researchers hypothesize that by reducing smoking and smoking-related illnesses and morbidity, higher cigarette taxes can reduce health care costs (Callison & Kaestner, 2014a) and shift the burden of those health care costs to smokers who may incur higher costs later in life (Chaloupka & Warner, 2000).

Despite these links, little empirical evidence exists on the relationship between cigarette taxes and health expenditures. We analyse the effect of cigarette taxes on state spending on health care using an approach that can help inform state policy-makers who regularly determine both state spending on health and health care and state excise taxes on cigarettes.

Our analysis builds on a recent federal government report assessing the effect of the federal cigarette excise tax on multiple aspects of the federal government budget (Congressional Budget Office, 2012). This paper extends recent research by Lightwood and Glantz (2011) and Lightwood and Glantz (2016) on the impact of cigarette taxation and smoking on state government health care spending. Our study also extends a growing body of research using spatial econometric methods to analyze sub-national government taxes and spending (Delgado, Lago-Peñas, & Mayor, 2015; López, Martínez-Ortiz, & Cegarra-Navarro, 2017; Segura, 2017).

We estimate dynamic spatial Durbin models that account for persistence and spatial dependence in both state health expenditure and cigarette taxes. We use pounds of tobacco grown in states as an instrument for cigarette tax rates to control for the impact of special interests on state policies and to ameliorate reverse causation concerns regarding state tax and expenditure policy. Our results show that increases in state cigarette taxes increase state expenditures on both health care and hospitals. We find the cigarette tax-expenditure elasticity to be 0.03 (SR) and 0.87 (LR) for state health care spending and 0.05 (SR) and 0.79 (LR) for state hospital spending.

2 | CIGARETTE TAXES, DEMAND, AND HEALTH SPENDING

Cigarette taxes can affect state health care expenditures through multiple channels. The most commonly assumed channel reflects the impact of cigarette taxes on individual cigarette smoking decisions. Most studies in this literature posit a negative relationship between cigarette taxes and state health care expenditures. This conclusion is based on two outcomes. First, higher cigarette taxes cause some smokers to quit, encourage a lower takeup rate of smoking among non-smokers, and reduce the intensity of smoking. Second, the decrease in cigarette consumption results in fewer smoking-related illnesses and smoking-attributable health care expenditures.

The respective literatures on both outcomes is large. For cigarette consumption, a range of price-elasticity estimates exist, but the literature generally agrees that higher cigarette taxes increase cigarette prices, and thus, decrease consumption (DeCicca & McLeod, 2008; Maclean et al. 2014, 2015). Demand curves slope downwards. Most cigarette elasticity of demand estimates range between –0.06 and –0.70.

For health expenditures, most studies focus specifically on the expected reduction in health care expenditures attributable to smoking-related illnesses and conditions (Lightwood, Dinno, & Glantz 2008; Lightwood & Glantz, 2011, 2016; Maciosek, Xu, Butani, & Pechacek, 2015). Medical expenses related to smoking, such as lung disease, stroke, and cancer, are expensive. Reducing smoking reduces smoking-related medical expenditures.

Lightwood and Glantz (2016) estimated that a 1% relative reduction in smoking prevalence is associated with a \$7.58 reduction in *per capita* healthcare expenditure, using data on aggregate measures of smoking behaviour for each of the 50 states and the District of Columbia from 1992 to 2009. In 2012, total health care expenditures in the US were \$2.8 trillion. These results suggest that, holding other common trends and factors affecting health care expenditures constant, a 10% relative drop in smoking would be followed in the next year by a \$63 billion reduction in healthcare expenditure (in 2012 dollars).

The Congressional Budget Office (2012) simulated the budgetary effects of a hypothetical increase of 50 cents per pack in the federal excise tax on cigarettes and small cigars (from \$1.01 per pack to \$1.51 per pack). They reported estimated public sector health care savings of nearly \$1 billion over ten years.

However, increases in cigarette taxes may not result in reduced overall health care expenditures. The increase in non-smoking health care expenditures attributed to longer life expectancies may exceed the reduction in smoking-related health care expenditures. This highlights the importance of both short-run and long-run estimates of the impact of cigarette taxes on government health spending.

Because life expectancy increases for those who quit smoking or never start smoking to begin with, long-term health care expenses may also increase. Viscusi (1995) estimated that for each pack of cigarettes a smoker no longer smokes, long-term heath care expenses increase by $0.23.[2] In a recent paper, Callison and Kaestner (2014b) found that the association between cigarette taxes and cigarette consumption was not statistically different from zero and argue that further increases in cigarette taxes may not result in reduced health care expenditures.

A separate channel for cigarette taxes to affect health expenditures comes from basic public finance principles. Cigarette taxes generate state tax revenues and governments spend those revenues. State government budget-makers often use tax revenue sources as a signal for where to place state budget priorities (Crowley & Hoffer, 2012). Greater gas tax revenues may signal budget-makers to spend more on roads. Cigarette taxes may signal the need for greater hospital and health care expenditures.

While it may seem obvious that cigarette tax revenues would be spent in this manner, several political economy studies suggest otherwise. Following 1998 the Master Settlement Agreement (MSA), under which US cigarette manufacturers agreed to pay state governments $246 billion over 25 years, McKinley, Dixon, and Devore (2003) found, on average, states spent 30% of their MSA revenues on health care, 5% on tobacco control programmes, and 44% on state endowments, budget reserves, and other expenditures, like closing budget deficits. Hoffer and Pellillo (2012) found that state tobacco production was associated with a significant decrease in support for funding programmes that discouraged smoking.

Based on the literature, the overall effect of cigarette taxes on health expenditures cannot be determined *a priori*. We estimate this relationship using reduced form empirical models. Estimating the relationship between cigarette tax rates and state health care expenditures is challenging for several reasons. First, spatial dependence affects both the dependent and independent variables in our analysis. A number of papers recognize the importance of cross-border shopping and smuggling and their effects on cigarette smoking and tax revenues (Chiou & Muehlegger, 2008; Connelly, Goel, & Ram, 2009; DeCicca, Kenkel, & Liu, 2013; Devereux, Lockwood, & Redoano, 2007; Goel & Nelson, 2012; Nelson, 2002). Pesko et al. (2016) examine the effect of within-state (local) variation in cigarette prices on smoking behavior and find that intrastate variation also plays a key role. This literature emphasizes the importance of spatial dependence when analysing the impact of cigarette taxes on other economic outcomes.

Second, races to the top and races to the bottom in both state tax and expenditure policy have been theorized and empirically analysed. Berry, Fording, and Hanson (2003), focusing on state welfare policies, found that bordering states make systematic policy changes in response to neighboring states' policies or expenditure changes. These spatial spillovers may extend to state health or hospital spending.

A related strand of literature focuses on the determinants of cigarette tax rates, including the influence of political factors and special-interest groups (Devereux et al. 2007; Gallet, Hoover, & Lee, 2009; Golden, Ribisl, & Perreira, 2014; Hoffer, 2016). An important conclusion emerging from this literature is the spatial endogeneity of cigarette tax rates. Hoffer (2016) explores the effect of tobacco special-interest groups on cigarette tax rates using spatial econometric methods to control for tax competition and endogeneity in state tax rates and finds that cigarette tax rates are highly persistent and spatially interdependent and finds evidence of strong special-interest effects. Hoffer and Lacombe (2017) emphasize the importance of spatial dependence in cigarette tax rates for non-health related reasons, and reinforce the idea that empirical analysis of the relationship between cigarette taxes and state health spending should account for spatial dependence in cigarette taxes.

In the context of a reduced from empirical model of the determination of state health spending, the nature of the relationship between cigarette taxes and state health spending is complex. Many potential channels driving this relationship exist. The literature reviewed above identifies several important econometric implications for a reduced

[2]The long-term health care expenses are concentrated in assisted living facility care. Even greater expenses are observed for Social Security and pension plans, but some of those public expenditures are offset by additional wages and taxes created by longer working careers

form analysis of cigarette taxes and state health spending. Short run impacts may differ from long run impacts, because short run impacts depend heavily on direct effects related to individual decisions to quit or reduce smoking while long run impacts depend on indirect effects related to longevity among former smokers. Spatial dependence is likely important, because cross border shopping and the practice of buying cigarettes in low tax states and illegally selling them in nearby high cigarette tax states at a discount (called "bootlegging") have important effects in this setting. The empirical methods used in our analysis explicitly address these issues.

3 | EMPIRICAL ANALYSIS

3.1 | Empirical methods

We estimate reduced form empirical models to explain the variation in real per capita state spending on health and hospitals over the period 1960–2007. The exact definitions of these types of state government spending are discussed in the Data section. The empirical models we use address the econometric issues and challenges discussed above.

A number of economic models can motivate simple reduced form empirical relationships like the one described here. Of course these reduced form models are subject to the standard criticisms related to model specification and do not make explicit assumptions about the effect of cigarette taxes on individual decisions to smoke or not smoke. However, one advantage of reduced form models is that they can uncover relationships between variables that state policy-makers control, providing practical information about the potential consequences of cigarette tax policy decisions.

3.1.1 | Reduced form regression models

A simple approach to understanding the relationship between state cigarette excise taxes and state spending on health uses linear reduced form regression models that explain observed variation in state spending on health using state-level covariates and variables to capture unobservable state-level heterogeneity. These models take the form:

$$Y_{S,t} = \alpha_S + \tau_t + X_{S,t}\beta + \eta_{S,t}, \tag{1}$$

where the dependent variables $Y_{S,t}$ is a measure of state spending on health in state S in year t. α_S is a vector of state fixed effects capturing time-invariant state-specific factors affecting state health spending like location, geographic features, climate, and other time-invariant factors in each state. τ_t is a vector of year dummy variables that captures time varying factors that affect state health spending across all states like business cycles, federal policy changes, secular trends in health spending, and other time varying factors.

$X_{S,t}$ is a vector of explanatory variables that vary across states and over time. This vector always contains the state excise tax per pack of cigarettes in real 2007 cents per pack, the fraction of the state's population under the age of 15 and the fraction of the state's population over the age of 65. We also include measures of the political ideology — ranging from zero to one, increasing as a politician is more liberal — in each state in some of the empirical models. We express all continuous variables in log format. The parameter estimates can be interpreted as spending elasticities.

α_S, τ_t and β are vectors of unobservable parameters to be estimated. $\eta_{S,t}$ is an equation error term that captures all other factors that affect state health spending. We assume that $\eta_{S,t}$ is a mean zero random variable with heteroscedasticity and possibly serial correlation. If estimated by ordinary least squares (OLS), Equation 1 is the common least squares dummy variable or two-way fixed effects model.

While reduced form linear regression models provide a basic picture of the relationship between cigarette taxes, demographic factors, and state political idealogy on state health and hospital spending, OLS estimates also have econometric limitations. In particular, when assessing the relationship between state cigarette taxes and state health spending, OLS estimates will be biased and inconsistent if any of the explanatory variables is correlated with the equation error term, $\eta_{S,t}$. In this context, it is likely that the cigarette tax variable is correlated with the equation error term, leading to econometric problems when estimating the elasticity of state health spending with respect to changes in state cigarette tax rates.

We address this problem by using the instrumental variables (IV) estimator, in the form of the standard two-stage-least squares (2SLS) estimator to Equation 1. We estimate a first stage regression model for the cigarette tax variable:

$$CT_{S,t} = \delta Z_{S,t} + X_{S,t}\beta + \varepsilon_{S,t}, \tag{2}$$

where $CT_{S,t}$ is the real state excise tax per pack of cigarettes in real 2007 cents per pack in state S in year t. $Z_{S,t}$ is a vector of instruments that explain state-level variation in cigarette taxes. If $\varepsilon_{S,t}$ is uncorrelated with $\eta_{S,t}$, then the predicted values from estimation of Equation 2, $\widehat{CT}_{S,t}$, can be used in place of the actual values of $CT_{S,t}$ in Equation 1 to obtain unbiased, consistent estimates of the elasticity of state health spending with respect to changes in state cigarette tax rates.

We use two instruments to estimate the parameters of Equation 2: the total pounds of tobacco produced in state S is year t; and the Gini coefficient on income in state S in year t. Pounds of tobacco grown serves as a credible instrument candidate. Hoffer (2016) describes how state cigarette tax policy cannot reverse cause agriculture yields but instead reflects the concentration of special interests in a state that lobby effectively for special treatment for the tobacco industry. This should be uncorrelated with unobservable factors affecting health and hospital spending. The Gini coefficient is a measure of income inequality that reflects how many relatively poor people live in a state, and thus the number of smokers available to be taxed since poorer people are more likely to smoke. This should explain cigarette tax rates but be uncorrelated with state health and hospital spending.

3.1.2 | Dynamic spatial lag panel model

The IV estimates discussed above may suffer from econometric problems like omitted variables bias and serial correlation. Results from an IV model also capture only the contemporaneous relationship between cigarette taxes and state spending on health. State expenditures on health are persistent over time because the general health and demographic characteristics of the residents of a state change slowly. French and Jones (2004) find that a highly persistent AR(1) process describes the typical data generating process for log health care costs.

State spending on health and hospitals may also be spatially correlated, if, for example, people live in one state and work in another, or seek medical care outside the state of residence. This spatial correlation can be the result of causal spatial interaction in the form of service competition or yardstick setting, or correlational spatial effects due to unobserved geographic spatial factors like proximity and differences in the provision of health care services across states.

Cigarette tax rates may also be spatially correlated. Accounting for these factors requires an empirical model that includes both time and spatial effects. To address these issues, we estimate a dynamic space-time panel model that includes a time autoregressive component and a spatial autoregressive component.

A dynamic spatial lag panel model captures the dynamic spatial relationship between state cigarette tax rates and state-level *per-capita* health expenditure. This model allows for time dependence in state health and hospital spending, spatial dependence in the dependent and explanatory variables, in particular spatial dependence in cigarette tax rates, and a cross-product term that captures spatial dependence lagged one period. Models of this form are called dynamic spatial Durban models or dynamic spatial lag panel models in the spatial econometrics literature.

The model provides considerable flexibility in terms of its ability to capture time and spatial dependence in the data. Debarsy, Ertur, and LeSage (2012) discuss the properties of dynamic spatial Durban models (DSDM) and the interpretation of the coefficients in these models. Lee and Yu (2015) point out that better models than the DSDM exist if time and space effects cannot be separated, but if time and space effects are separable, the computational gains from the DSDM prove superior to existing models for practical estimations (Parent & LeSage, 2012).

The dynamic spatial lag panel regression model takes the form:

$$Y_{S,t} = \varphi Y_{S,t-1} + \rho W Y_{S,t} + \gamma W Y_{S,t-1} + \tau_t + X_{S,t}\beta + WX\Theta_{S,t} + \mu_S + \eta_t. \tag{3}$$

Following Debarsy et al. (2012), Equation 3 can be solved for Y and transformed into space, time, ans space-time filters. The time filter, A is a $T + 1$ x $T + 1$ matrix containing a Praise-Winsten transformation for the initial period using 1960 data as the initial period values. The spatial filter, B, and space-time filter are nonsingular matrices that take the form:

$$A = -[\varphi I_N + \gamma W], \tag{4}$$

$$B = [I_N - \rho W], \tag{5}$$

$$C = -[\varphi I_N + \theta W], \tag{6}$$

$$A \otimes B = I_{N,T+1} - \rho I_{T+1} \otimes W - \varphi L \otimes I_N + (\rho\varphi) L \otimes W, \tag{7}$$

where L is the $(T + 1), (T + 1)$ matrix time-lag operator. Conveniently, only A and B^{-1} need to be calculated to analyse the partial derivative impacts for any time horizon T. Debarsy et al. (2012) identify the proper contemporaneous interpretation of the own- and cross- partial derivatives resulting from a change in the r^{th} explanatory variable in state i:

$$\frac{\partial Y_{T+1}}{\partial X_t^r} = [D_1 + B^{-1}][I_N \beta_r + W\gamma_r], \tag{8}$$

where:

$$D_S = (-1)^S (B^{-1}C)^S B^{-1}, s = 0, \cdots, T - 1. \tag{9}$$

More generally, the cumulative (T-period ahead) impact arising from a one-time change in $X_{r,t}$ at time, t, is:

$$\frac{\partial Y_{T+1}}{\partial X_t^r} = \sum_{i=0}^{T} (D_s [I_N \beta_r + W\gamma_r]). \tag{10}$$

An additional advantage of Equation 3 over the IV model discussed above is that this model can account for a number of temporal and spatial factors that may affect state spending on health and hospitals and the relationship between these variables and cigarette taxes. The model accounts for persistence in state health and hospital spending as reflected in the parameter φ. Again, the underlying health of the population of a state affects state spending on health and hospitals, and changes slowly over time due to factors like the prevalence of chronic conditions in a state and individual state residents' decisions about healthy behaviours like diet, smoking, and physical activity.

The model also reflects spatial dependence in state spending on health care through the parameter ρ, working through the spatial weights matrix W. This effect could be particularly important in hospital spending, where one state's decision on hospital spending could affect the level of spending in neighboring states. For example, one state might choose to spend relatively little on specialty hospital care so that state residents seek specialty hospital care in neighbouring states.

The model also captures spatial dependence in state cigarette tax rates through the parameter θ. Spatial dependence in cigarette tax rates can reflect incentives for cross-border shopping for cigarettes or bootlegging of cigarettes purchased in nearby low tax states.

3.2 | Data

The data on state-specific spending on hospitals and health care for the contiguous 48 states over the period 1960 to 2007 come from State Government Finances, a Census Bureau survey that contains annual estimates of state government spending. These surveys contain estimates of state government revenues by source of revenue and spending by both object of spending and function of spending. Spending by function is designed to capture state spending for specific purposes served by government activities, including high-level functions like education, highways, public welfare and health. The estimates by function of spending are designed to be comparable across states and over time. We collected data on two State Government Finances functional areas: spending on health and spending on hospitals.

State spending on health includes spending on outpatient health services that does not include hospital care. This includes spending on public health administration, research and education, categorical health activities like tuberculosis or cancer control programmes, treatment and immunization clinics, nursing, environmental health activities like air and water pollution control, ambulance services if they are provided separately from fire protection services, and other general public health activities like mosquito abatement. It also includes school health services provided by health agencies, but not school health services provided by school agencies. In general, this represents indirect spending on health care.

State spending on hospitals includes state financing, construction, maintenance or operation of state hospital facilities, provision of hospital care in state hospitals, and state support of health care in other public or private hospitals. State hospitals are defined as facilities administered directly by the state government. State support for other hospitals refers to state support for hospital services in private hospitals or hospitals operated by other levels of government like cities or counties. Spending on nursing homes is not included but is captured under the public welfare function unless they are directly associated with a government hospital. This functional area represents direct spending on health care.

State government payments to vendors made directly to private suppliers of medical care, burials, and other health-related commodities and services provided under welfare programs are not included in the health or hospital functional areas; these payments fall under the public welfare function in State Government Finances. Nursing homes are also included in the public welfare functional area, unless they are directly associated with a state owned and operated hospital.

Data on state excise taxes on cigarettes are available in *The Tax Burden on Tobacco Volume 49, 1970–2014* available at http://www.healthdata.gov/dataset/ back to 1970. State cigarette excise taxes before 1970 are available in Orzechowski and Walker (2008). The state-level demographic variables, the fraction of the population over 65 and under 15 were collected from the Census Bureau's *Annual Population Estimates* (http://www.census.gov/popest/). The cigarette excise tax and state expenditure variables are deflated to real 2007 dollars using the Consumer Price Index for All Urban Consumers (CPI-U).

Table 1 contains summary statistics for the health spending, hospital spending, cigarette tax, demographic, and political ideology variables. Total state spending on health and hospitals are expressed in thousands of real 2007

TABLE 1 Summary statistics

	Mean	sd	Min	Max
Health spending (1,000)	507,753	974,105	4,840	11,196,681
Per capita health spending	91.80	72.84	3.86	420.20
Hospital spending (1,000)	634,608	812,341	883.30	5,756,363
Per capita hospital spending	121.05	66.08	1.42	463.23
Per capita personal income	26,566	7,516	8910	56723
Cigarette tax (cents/pack)	44.28	29.43	0.00	261.17
Pct. population white	86.58	9.49	57.70	99.80
Pct. population under 15	24.59	4.19	17.10	37.90
Pct. population over 65	11.40	2.12	5.40	18.30
Politician ideology	47.99	24.06	0.00	99.39
State Gini coefficient	0.38	0.04	0.31	0.50
Tobacco production (lbs)	33,227,287	112,986,692	0	87,7729,569
Observations	2,304			

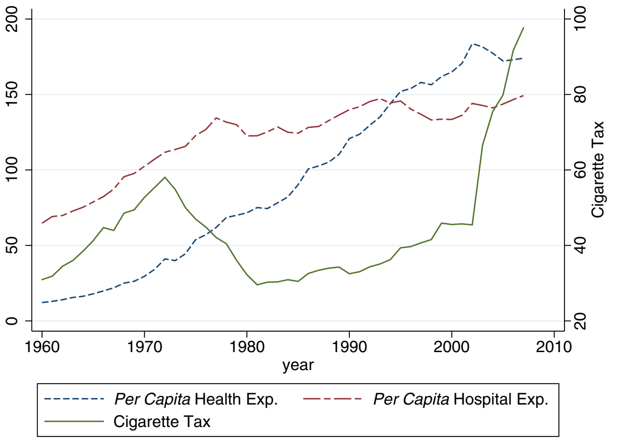

FIGURE 1 Health spending *per capita* and cigarette taxes 1960–2007

dollars. Average annual state-level spending on health was about $507 million; average annual state spending on hospitals was about $635 million. The maximum values are both for California, which spent as much as $11 billion annually on health and $5.7 billion on hospitals. The average state excise tax on cigarettes was 44 cents a pack over the sample period.

Figure 1 graphs the average annual per capita spending across all states on health and hospitals over time, along with the average real excise tax on cigarettes in real 2007 cents per pack. Average annual state per capita spending on health and hospitals increased steadily over the period from about $60 per resident on hospitals and about $20 per resident on health in the 1960s to over $150 per resident on both health and hospitals in 2007.

Real state *per capita* spending on hospitals was higher earlier in the sample, but in the early 1990s, annual state *per capita* spending on health exceeded spending on hospitals. That gap has persisted. Average cigarette taxes increased in real terms in the 1960s and decreased substantially in the 1970s, probably because these taxes were not indexed to inflation. Average cigarette tax rates rose again in the 1980s and 1990s, but not as fast as in the 1960s or 2000s. Real average cigarette taxes increased substantially in the 2000s.

3.3 | Instrumental variables results

Table 2 contains instrumental variables (IV) results using the fitted values from the first stage regression model defined by Equation 2 to replace actual cigarette tax values in Equation 1. The first-stage OLS results are presented in Table A1 in the Appendix. All variables are expressed in logs so that the coefficient estimates of our regressions can be interpreted as a one percent change in the independent variable resulting in a β percentage change in the dependent variable.

Models (1) and (4) in Table 2 have only the real state excise tax per pack on cigarettes as an explanatory variable, along with state and year fixed effects. Models (2) and (5) add additional control variables to these models that have been shown to explain spending on health and hospitals. These variables include real state personal income *per capita*, the fraction of the state population that is white, the fraction of the state population under the age of 15, and the fraction of the state population that is over the age of 65. Models (3) and (6) add the political ideology variable.

The first stage regression model contained two instruments: pounds of tobacco produced in each state in each year and the Gini coefficient on household income in each state in each year. Cigarette taxes vary with state tobacco production because of the lobbying efforts by special interests in states with high tobacco production (Hoffer, 2016). The strength of the tobacco lobby in a state should be uncorrelated with unobservable factors affecting state health and hospital spending. Inequality in state household income could affect cigarette taxes because cigarette smoking

TABLE 2 IV results: robust standard Errors

DV is spending on:	(1) Hospital	(2) Hospital	(3) Hospital	(4) Health	(5) Health	(6) Health
Cigarette tax	0.140**	0.074*	0.069*	0.023	0.048**	0.057**
	2.92	1.71	1.59	1.07	2.70	3.16
Per capita pers. inc.	–	0.913***	0.908***	–	−0.216	−0.190
		4.26	4.26		−1.55	−1.36
Pct. pop white	–	−1.055**	−1.002**	–	0.473**	0.392*
		−3.18	−3.01		2.82	2.29
Pct. pop under 15	–	−3.211***	−3.238***	–	1.130***	1.189***
		−8.75	−8.83		4.13	4.31
Pct. pop over 65	–	-1.960***	−1.950***	–	0.697***	0.679***
		−8.22	−8.17		4.69	4.57
Political ideology	–	–	−0.020	–	–	0.037***
			−1.11			3.30
Instrument validity tests						
Stock-Yogo first stage F	51.6	28.16	27.66	51.7	28.15	27.66
Sargan χ^2	0.058	0.078	0.14	3.42	1.41	1.32
(Significant = invalid)	(p = 0.78)	(p = 0.77)	(p = 0.71)	(p = 0.06)	(p = 0.23)	(p = 0.25)
Wooldridge robust score	0.075	2.76	3.96	15.4	6.03	5.37
(H_o : Exogenous)	(p = 0.78)	(p = 0.09)	(p = 0.04)	(p = 0.01)	(p = 0.01)	(p = 0.02)
Observations	2,304	2,304	2,300	2,304	2,304	2,300

Notes: t statistics identified below coefficient estimates. *p ≤ 0.10, **p ≤ 0.05, ***p ≤ 0.01.

decreases with income. Greater income inequality in a state means more relatively poor people, and more potential cigarette smokers to tax. This should also be uncorrelated with unobservable factors affecting state health and hospital spending.

We fail to reject instrument invalidity in each model other than (4), suggesting our instruments are relatively strong. The Stock-Yogo first stage F statistics are quite large, and the Sargan χ^2 statistics are generally insignificant. The coefficient on cigarette tax is positive for each model specification. The coefficients are statistically different from zero in models (2)–(6). The IV estimates suggest that the contemporaneous effect of a one percent increase in a state's cigarette tax rate is an increase in health expenditures of 0.05 to 0.06%. The same increase in cigarette tax rates increase hospital expenditures by about 0.07 to 0.14%.

The parameter estimates on the other control variables that are commonly associated with state spending on health and hospitals are generally statistically different from zero but exhibit some variation in direction. *Per capita* income is positively associated with spending on hospitals but is not associated spending on health. However, states with a larger white population and larger populations under 15 and over 65 spend more on health but less on hospital care. States with politicians with a more liberal ideology spend more on health.

The IV model still suffers from uncorrected spatial endogeneity. To account for spatial effects, we next estimate a dynamic spatial lag panel (DSLP) model. We further obtain estimates of both the short-run and long-run tax rate-expenditure elasticities.

3.4 | Dynamic spatial lag panel model results

We estimate the DSLP, Equation 3, using the Bayesian Markov chain Monte Carlo (MCMC) estimation procedure developed in Parent and LeSage (2012). We use the fitted values from the first stage model given by Equation 2 to define our primary independent variable of interest, cigarette tax rates.

TABLE 3 DSLP results: state hospital spending, model (3)

Space/time filter parameters	Lower 0.01	Mean	Upper 0.01
φ (time AR)	0.9396	0.9609	0.9817
ρ (spatial AR)	−0.2585	0.0458	0.1221
θ (space-time AR)	−0.1148	−0.0617	0.0095
$-\rho * \varphi$	−0.1176	−0.0440	0.0274
σ^2	0.0214	0.0231	0.0250
σ_μ^2	0.0009	0.0019	0.0040
Covariates			
Cigarette tax	−0.0097	0.0092	0.0284
Per capita pers. inc.	−0.1002	0.0049	0.1150
Pct. pop white	−0.2215	−0.0511	0.1200
Pct. pop under 15	−0.3150	−0.0744	0.1624
Pct. pop over 65	−0.2007	−0.0735	0.1200
Political ideology	−0.0090	−0.0079	0.0249

Table 3 reports the estimates for the model parameters based on 200,000 MCMC draws with the first 100,000 discarded to account for burn-in of the sampler. The estimates are for the model parameters based on the specifications shown by model (3) in Table 2, which contains real state *per capita* income, the percentage of state population that is white, state population percentage under 15, state population percentage over 65, and political ideology as explanatory variables. We report the posterior mean, lower 0.01 value and upper 0.99 percentile value constructed using the retained draws. The spatial weight matrix is based on state spatial contiguity.

In Equation 3, φ reflects persistence in the dependent variable, real state spending per capita on hospitals. This form of spending is highly persistent over time, reflecting slow changes in the underlying health of a state's residents, which depends on factors like age and decisions about health behaviors like diet and physical activity, consistent with the results reported in French and Jones (2004). The estimates for both ρ and θ span zero, so we cannot reject the null hypothesis of no spatial dependence in state hospital expenditures.

Following common spatial econometric practice, we focus on estimates of the partial derivative effects associated with changing the cigarette tax variable in Equation 3. This space-time dynamic model has both own- and cross-partial derivatives that reflect the impact of changes in a state's cigarette tax at time *t* on own-state and neighbouring state spending on hospitals at time *t*. The model also contains a cross-partial derivative $\frac{\partial Y_{St}}{\partial X_S}$ that reflects the contemporaneous spatial spillover effect of cigarette taxes in bordering states on hospital spending in state *S*.

Partial derivatives that quantify the magnitude and timing of state hospital spending changes in each state at various time horizons in response to changes in cigarette taxes at time *t* can be calculated from Equation 3. The DSLP approach generates two different estimated impacts of cigarette taxes. First, a transitory (or one-period) change in hospital spending, reflected in the mean and upper/lower 10% values in Table 4. Second, the permanent or sustained change in the level of hospital spending, caused by a combination of policy-persistence and lagged spatial feedback effects, labelled "cumulative impact" in Table 4.

Using the initial year of data, we can calculate the effects of a one-time change in a state's cigarette tax rate on health care expenditures 47 years later. We call the contemporaneous change the short-run elasticity and the cumulative $t + 47$ change the long-run elasticity.

We are also able to differentiate between the direct, indirect, and total effects. Direct effects represent the effect that a change in an independent variable has on its own state's dependent variable and indirect effects quantify the cumulative "spillover effects" resulting from spatial dependency. Total effects are the sum of the direct and indirect effects. Table 4 shows the estimated partial derivative effects and cross-partial derivative effects reflecting the impact of a change in cigarette taxes on state hospital spending, based on the model specification shown by model (3) in Table 2.

TABLE 4 Dynamic spatial lag panel partial derivatives: state hospital spending

Periods	Cumulative effect	Lower 0.10	Mean	Upper 0.10
Total effects				
0	0.046	0.026	0.046	0.066
1	0.089	0.024	0.043	0.062
2	0.129	0.023	0.041	0.059
3	0.167	0.021	0.038	0.056
4	0.203	0.020	0.036	0.053
5	0.237	0.019	0.034	0.050
47	0.789	0.001	0.004	0.124
Direct effects				
0	0.010	−0.003	0.010	0.022
1	0.019	−0.003	0.009	0.021
2	0.027	−0.003	0.009	0.020
3	0.035	−0.003	0.008	0.019
4	0.043	−0.003	0.008	0.018
5	0.050	−0.003	0.007	0.017
47	0.174	−0.002	0.001	0.004
Indirect effects				
0	0.036	0.016	0.036	0.056
1	0.070	0.015	0.034	0.053
2	0.102	0.014	0.032	0.050
3	0.132	0.013	0.030	0.048
4	0.160	0.012	0.028	0.045
5	0.187	0.011	0.027	0.043
47	0.615	−0.003	0.003	0.010

The total effects point estimates are positive and the confidence intervals do not contain zero. These estimates suggest that a 10% increase in a state's cigarette tax rate will increase hospital expenditures by 0.46% in the first year of the tax. Those hospital expenditures will persist over time. Forty seven years after the initial 10% cigarette tax rate increase, hospital expenditures will have increased by 7.9%. For the average state, that translates to about $2 million in the first year and $50 million over the next several decades.

Disaggregated by direct and indirect effect, we observe that the majority of the total effect comes from the indirect or "spillover" effects. In fact, the direct effect estimates span zero, so we cannot be confident of any non-zero direct effect of cigarette taxes on hospital expenditures. This finding is a common theme in most of our empirical results and emphasizes that public policy in US states does not occur in a vacuum. The spillover effects are important.

So, why would an increase in New York's cigarette tax rate affect hospital expenditures in Pennsylvania? One plausible answer is tax revenue lost and gained via smuggling and cross-border shopping. Recent estimates suggest the inbound smuggling rate of cigarettes into New York is between 55 and 62% (LaFaive et al. 2016). The tax revenue on those smuggled cigarettes would constitute $1.63 billion.

Interestingly, we see the indirect effects stay positive, even when we control for revenue changes later in the paper. Many other possibilities could be driving this outcome, including short-run behavioural changes, migration decisions, and factors related to the additional longevity afforded by cigarette cessation, but we are unable to directly test any of those factors.

Turning to health expenditures, Table 5 contains the autoregressive parameter estimates using state health spending as the dependent variable. The estimates are for the model parameters based on the specification shown

TABLE 5 DSLP results: state health spending, model (6)

Space/time filter parameters	Lower 0.01	Mean	Upper 0.01
φ (time AR)	0.8768	0.9000	0.9205
ρ (spatial AR)	0.0966	0.1407	0.1947
θ (space-time AR)	–0.1089	–0.0562	–0.0172
$-\rho * \varphi$	–0.1755	–0.1266	0.0874
σ^2	0.0196	0.0211	0.0229
σ_μ^2	0.0009	0.0019	0.0040
Covariates			
Cigarette tax	–0.0133	0.0060	0.0248
Per capita pers. inc.	0.0111	0.1101	0.2152
Pct. pop white	–0.2337	–0.0768	0.0750
Pct. pop under 15	–0.1601	0.0526	0.2669
Pct. pop over 65	–0.1403	–0.0312	0.0820
Political ideology	–0.0045	0.0065	0.0177

by model (6) in Table 2. Similar to hospital expenditures, state expenditures on health are highly persistent over the sample period. Unlike hospital expenditures, however, state health expenditures reflect significant spatial correlation. This finding supports the positive spatial relationship in state AFDC spending reported by Berry et al. (2003). Because state health spending has been broadly increasing, the positive coefficient on ρ represents more of a "race to the top" in health spending, as opposed to the hypothesized "race to the bottom" in other social programme spending.

Table 6 presents the estimated partial derivative effects and cross-partial derivative effects reflecting the impact of a change in cigarette taxes on state health spending. Similar to hospital expenditures, we observe positive estimates for indirect and total effects that do not span zero. The mean direct effect estimates are positive, but the confidence interval span zero.

The mean current impacts are small and positive. In total, a 10% increase in a state's cigarette tax rate increases health care expenditures by 0.26 % the first year. That effect grows to 8.73 % over 47 years due to health expenditure persistence.

The positive long-run cumulative increase in state health spending generated by cigarette tax increases supports the hypothesis that increasing cigarette taxes reduces smoking take up and the intensity of smoking by current smokers, which leads to increased life spans for state residents. Longer lived residents place additional demands on state health services, increasing spending in this functional area.

Taken together, we find no spatial dependence (ρ) in state hospital expenditures but spatial dependence in state health expenditures. The lack of spatial dependence in public hospital spending is not surprising because patients going to state-funded hospitals are not likely to cross borders for hospital care or work in one state and live another state. There is less likely to be cross state competition for state hospital services. Service or yardstick competition across state borders is more likely to occur among private hospitals.

The manner in which states funds are allocated to hospital and health spending might also explain why there is spatial dependence in health spending but not in hospital spending. Payments to state hospitals reflect a state appropriations decision that are less likely to be influenced by appropriations decisions of bordering states. However, spending on public health programs is more reflective of state policy decisions that are more likely to be influenced by policy decisions in bordering states.

3.5 | Robustness analysis

We consider several extensions to our DSLP analysis. First, both state hospital and state health expenditures may be non-stationary. In this section, we test for stationarity using four popular tests: (i) the Harris-Tzavalis test; (ii) the

TABLE 6 Dynamic spatial lag panel partial derivatives: state health spending

Periods	Cumulative effect	Lower 0.10	Mean	Upper 0.10
Total effects				
0	0.026	0.009	0.026	0.043
1	0.052	0.008	0.026	0.043
2	0.077	0.008	0.025	0.042
3	0.101	0.008	0.025	0.041
4	0.125	0.008	0.024	0.041
5	0.149	0.008	0.024	0.040
47	0.873	0.002	0.013	0.029
Direct effects				
0	0.006	−0.006	0.006	0.018
1	0.013	−0.005	0.006	0.017
2	0.018	−0.004	0.006	0.015
3	0.024	−0.003	0.005	0.014
4	0.029	−0.003	0.005	0.013
5	0.034	−0.002	0.005	0.012
47	0.118	0.000	0.001	0.002
Indirect effects				
0	0.020	0.004	0.020	0.035
1	0.039	0.005	0.019	0.034
2	0.058	0.005	0.019	0.034
3	0.078	0.006	0.019	0.033
4	0.097	0.006	0.019	0.033
5	0.116	0.006	0.019	0.033
47	0.755	0.002	0.012	0.027

Breitung test; (iii) the Dickey-Fuller test, and the Pesaran, Smith, and Yamagata (2013) CADF test. We then estimate our Bayesian models again, replacing our dependent variables with the first difference of those variables. Finally, we estimate maximum likelihood models with common factors, following Ciccarelli and Elhorst (2017).

Second, the overall impact cigarette taxes play on state hospital and health expenditures is a combination of two effects: the effect emanating from a decline in smoking behaviour; and the effect resulting from state revenues generated by cigarette tax. In our initial DSLP estimates, these effects are inseparable. In this section, we present results in which we include real total state own-source revenue collection *per capita* as an independent variable in both the first and second stage regressions. In this model, the revenue collection variable captures the general revenue effects of taxation on hospital and health care expenditures, allowing the cigarette tax variable to potentially capture the effects resulting from the decline in cigarette consumption.

Finally, we rerun most of our models without using any instruments. For space consideration, we place these findings in the Appendix. While we think that our instruments, pounds of tobacco produced and the state Gini coefficient of household income, are credible instruments that improve the accuracy of our estimates, we recognize the difficulty in making an iron clad case for instrument validity. For transparency, we offer the non-instrumented DSLP results in Tables A2 and A3 and the bias-corrected ML common factor estimates in Table A4 in the Appendix.

3.5.1 | Non-stationarity

Some concern exists that state spending on health and hospitals may reflect a non-stationary data generating process like an I(1) process. While Figure 1 could appear to be non-stationary, the time-series plots on Figure 1 are not the dependent variable used in the regression models. Figure 1 shows the average annual expenditure across all states. Individual plots of state-level health and hospital spending exhibit highly variable patterns over time.

Also, recall that French and Jones (2004) conclude that log health costs can be best represented by a white noise process and a highly persistent AR(1) process, not a non-stationary I(1) process. The results in Tables 3 and 5 have time AR parameters consistent with this. In addition, I(1) processes can drift arbitrarily far from their mean value over time. It seems implausible that state health and hospital spending would exhibit arbitrarily large deviations from some mean level due to the inability of states to raise tax revenues to pay for arbitrarily large levels of health or hospital spending.

Table 7 presents four common time series tests for stationarity. We note the null hypothesis for each test, the estimated test statistic, and the p-value of each statistic below the test statistic. Each test tells a similar story. Unit root is a concern for hospital expenditures, but not for health care expenditures. When we first-difference the dependent variable, all tests strongly reject non-stationarity.

Table 8 and Table 9 present the respective autoregressive parameter and the cigarette tax partial derivatives using the first difference in hospital expenditures as the dependent variable. If the underlying data generating process for health and hospital spending is a highly persistent AR(1) process, and not a non-stationary I(1) process, then these results have been "over-differenced" and contain all the well-known economic problems associated with "over-differencing."

By using the first-difference as the dependent variable, the strong, positive time dependence goes away, as expected. The time autoregressive parameter becomes negative. The estimates for both ρ and θ span zero, so, as was the case with state hospital spending expressed in levels, we cannot reject the null hypothesis of no spatial dependence in state hospital expenditures. The key result remains unchanged.

The indirect and total effects estimates for the cigarette tax rate remain positive and statistically different from zero. Instead of increasing in cumulative magnitude over time, the first period effects represent the maximum effect, shrinking in the subsequent period with a negative marginal effect, and then adding no marginal effect from periods T+2 onward. A 10% increase in a state's cigarette tax rate would have a 0.34% increase in the growth rate of

TABLE 7 Stationarity tests

Test	Hospital	Health care	ΔHospital	Δhealth care
Harris-Tzavalis test statistic	0.94	0.96	−20.75	−0.07
Ho: panels contain unit roots	0.73	0.97	0.00	0.00
Breitung test statistic	4.29	11.13	−22.05	−22.05
Ho: panels contain unit roots	1.00	1.00	0.00	0.00
Dickey-Fuller test statistic	71.92	147.6	955.14	904.87
Ho: all panels contain unit roots	0.97	0.00	0.00	0.00
CADF test statistic	4.14	−3.84	−22.19	−22.34
Ho: all series are non-stationary	1.00	0.00	0.00	0.00

TABLE 8 DSLP results: change in state hospital spending, model (3)

Space/time filter parameters	Lower 0.01	Mean	Upper 0.01
φ (time AR)	−0.1688	−0.1144	−0.0597
ρ (spatial AR)	−0.0214	0.0663	0.1515
θ (space-time AR)	−0.0727	0.0496	0.1688
$-\rho * \varphi$	−0.0024	0.0076	0.0198
σ^2	0.0215	0.0233	0.0252
σ^2_μ	0.0007	0.0013	0.0026

TABLE 9 DSLP partial derivatives: change in state hospital spending

Periods	Cumulative	Lower 0.10	Mean	Upper 0.10
Total effects				
0	0.034	0.015	0.034	0.052
1	0.031	−0.006	−0.002	0.001
2	0.031	0.000	0.000	0.001
3	0.031	0.000	0.000	0.000
4	0.031	0.000	0.000	0.000
5	0.031	0.000	0.000	0.000
46	0.031	0.000	0.000	0.000
Direct effects				
0	0.007	−0.005	0.007	0.019
1	0.006	−0.002	−0.001	0.001
2	0.006	0.000	0.000	0.000
3	0.006	0.000	0.000	0.000
4	0.006	0.000	0.000	0.000
5	0.006	0.000	0.000	0.000
46	0.006	0.000	0.000	0.000
Indirect effects				
0	0.027	0.008	0.027	0.046
1	0.025	−0.005	−0.002	0.001
2	0.025	0.000	0.000	0.001
3	0.025	0.000	0.000	0.000
4	0.025	0.000	0.000	0.000
5	0.025	0.000	0.000	0.000
46	0.025	0.000	0.000	0.000

TABLE 10 DSLP results: change in state health spending, model (5)

Space/time filter parameters	Lower 0.01	Mean	Upper 0.01
φ (time AR)	−0.1877	−0.1335	−0.0788
ρ (spatial AR)	0.0192	0.1036	0.1884
θ (space-time AR)	−0.2040	−0.0950	0.2115
$-\rho * \varphi$	0.0024	0.0138	0.0284
σ^2	0.0206	0.0223	0.0241
σ^2_μ	0.0005	0.0010	0.0019

that state's hospital expenditures, modestly shrinking to a 0.31% long-run increase in the state's hospital spending growth rate.

The autoregressive parameter and cigarette tax partial derivatives using the first difference in state health care expenditures are presented in Table 10 and Table 11. First-differencing the state health expenditure series produces results similar to those for the first-differenced state hospital spending series in that there is no longer evidence of strong, positive time dependence. Similar to levels of state health spending, growth in health spending reflect significant spatial correlation.

The results for the estimated partial derivative effects and cross-partial derivative effects mirror those of hospital expenditures but are slightly smaller in magnitude. A ten percent increase in the cigarette tax rate correlates with a

TABLE 11 DSLP partial derivatives: change in state health spending

Periods	Cumulative	Lower 0.10	Mean	Upper 0.10
Total effects				
0	0.018	0.001	0.018	0.036
1	0.017	−0.003	−0.001	0.001
2	0.017	0.000	0.000	0.000
3	0.017	0.000	0.000	0.000
4	0.017	0.000	0.000	0.000
5	0.017	0.000	0.000	0.000
46	0.017	0.000	0.000	0.000
Direct effects				
0	−0.002	−0.012	−0.002	0.009
1	−0.001	−0.001	0.001	0.002
2	−0.001	0.000	0.000	0.000
3	−0.001	0.000	0.000	0.000
4	−0.001	0.000	0.000	0.000
5	−0.001	0.000	0.000	0.000
46	−0.001	0.000	0.000	0.000
Indirect effects				
0	0.020	0.002	0.020	0.038
1	0.018	−0.004	−0.001	0.001
2	0.019	0.000	0.000	0.001
3	0.019	0.000	0.000	0.000
4	0.019	0.000	0.000	0.000
5	0.019	0.000	0.000	0.000
46	0.019	0.000	0.000	0.000

0.18% short-run increase in the health expenditure growth rate and a 0.17% long-run increase increase in the health care expenditure growth rate.

A separate approach to address potential non-stationarity involves controlling for common factors. The use of common factors to address non-stationarity evolved over the past several years. Pesaran et al. (2013) first used common factors to address potential non-stationarity in a dynamic, non-spatial model. Bailey, Holly, and Pesaran (2016) who used them to address potential non-stationarity in a dynamic, spatial model with no explanatory variables. Finally to Ciccarelli and Elhorst (2017), who used common factors to address potential non-stationarity in a full dynamic spatial model containing explanatory variables.

In this study, we follow the common factor procedure developed by Ciccarelli and Elhorst (2017). Using global common factors, we analyse the effect of cigarette taxes after first testing for spatial dependence using the CD test of Pesaran (2015) and testing for spatial stability following Yu, De Jong, and Lee (2008).[3]

In Table 12, we use two separate common factors: (i) the cross-sectional average of all dependent variable observations, $\bar{y}$; and (ii) the cross-sectional average of each independent variable, $\bar{X}$, in the first stage regression, Equation 2, when estimating Equation 3. The common factors can be treated as exogenous explanatory variables based on the assumption that the contribution of each single state to the cross-sectional averages at a particular point in time goes to zero as N grows larger (Ciccarelli & Elhorst, 2017). All reported coefficients in Table 12 are bias-corrected estimates, following the procedure in Yu et al. (2008).

[3]We are particularly grateful to Paul Elhorst for sharing the MATLAB code he developed to conduct these analyses

TABLE 12 Maximum likelihood one-period total effects with common factors

	State hospital spending				State health care spending			
	β	t-stat	β	t-stat	β	t-stat	β	t-stat
φ	1.01	104.1	0.43	22.89	0.76	51.52	0.46	24.85
θ	−0.03	−0.79	−0.09	−2.18	−0.16	−3.86	−0.09	−2.21
ρ	0.07	1.95	0.01	0.23	0.05	1.49	−0.04	−0.89
Cigarette tax	0.03	2.32	1.46	3.11	0.00	0.230	0.60	2.90
Per capita pers. inc.	0.05	0.93	0.02	0.06	0.13	1.77	0.32	1.46
Pct. pop white	0.04	0.30	0.31	1.00	0.16	1.18	0.44	2.15
Pct. under 15	−0.20	−2.10	−0.244	−0.60	−0.08	−0.88	0.99	3.94
Pct. over 65	−0.03	−0.33	0.07	0.21	0.12	1.29	0.32	1.56
Political ideology	0.00	0.03	1.36	4.52	0.01	1.39	0.50	2.42
Common factors	$\bar{y}$		$\bar{y}, \bar{X}$		$\bar{y}$		$\bar{y}, \bar{X}$	
$\varphi + \theta + \rho - 1$	0.040	3.03	−0.660	189.3	−0.349	84.74	−0.666	205.08
CD statistic	1.86		−1.356		2.890		−0.938	
R^2	0.875		0.924		0.975		0.982	
R^2 corrected	0.873		0.924		0.975		0.982	

The CD test statistic, whose null hypothesis is that the estimation residuals exhibit only weak (opposed to strong) cross-section dependence, suggests that we do an adequate job controlling for common factors, leaving minimal cross-section dependence unexplained and accounted for in the residuals. Also, following Yu, De Jong, and Lee (2008), our common factor maximum likelihood estimates report that the sum of $\varphi + \theta + \rho$ - 1 is statistically different from zero in each model specification, satisfying the spatial stability condition.

The total effect estimates in Table 12 support our earlier findings related to the effects of cigarette taxes on hospital and health care expenditures. Per capita hospital expenditures increase as cigarette tax rates increase. Using a common factor of $\bar{y}$, the tax-expenditure elasticity was 0.03. Using the averages for the dependent and independent variables as common factors, the point-estimate for the tax-expenditure elasticity increased dramatically to 1.46. A coefficient change of this magnitude is not uncommon when including common factors of independent variables, as the direct interpretation of the marginal effects changes with the inclusion of $\bar{X}$ as an additional explanatory variable.[4]

For health care expenditures, cigarette tax rates did not have a statistically significant impact in the model using $\bar{y}$ as a common factor. Using common factors for the dependent and independent variables, the model estimates in the last column of Table 12 suggest cigarette tax rate increases exhibit a rate-expenditure elasticity of 0.60. Again, this is a substantially larger point estimate than any of our previous estimates, however, we note that the positive sign on the coefficient is consistent with our the previous results.

Alternatively, non-stationarity can be addressed by further adding a spatial component, $\rho WC_{S,T}$, to Equation 2 and again using the fitted values from this first stage as an explanatory variable in Equation 3. Again, the common factors can be treated as exogenous explanatory variables (Ciccarelli & Elhorst, 2017). Table 13 contains the results using this alternative first-stage model.

The results in Table 13 are very similar to those in Table 12. The CD test statistic again suggests that the model adequately controlling for common factors, leaving minimal cross-sectional and spatial dependence unexplained by the residuals. The sum of $\varphi + \theta + \rho$ - 1 is again statistically different from zero in all model specifications, satisfying the spatial stability condition.

The total effect estimates in Table 13, like those in Table 12, support our earlier findings related to the effects of cigarette taxes on hospital and health care expenditures. For health care expenditures, cigarette tax rates still do not

[4]For an additional example, note the coefficients in column M5 in Table 1 of Ciccarelli and Elhorst (2017).

TABLE 13 Maximum likelihood one-period total effects with spatial common factor

	Hospital expenditures				Health care expenditures			
	β	t-stat	β	t-stat	β	t-stat	β	t-stat
φ	1.03	113.1	0.43	22.88	0.76	51.27	0.46	24.77
θ	0.00	−0.06	−0.09	−2.15	−0.16	−3.80	−0.08	−2.03
ρ	0.03	0.70	0.01	0.15	0.04	1.26	−0.04	−1.03
Cigarette tax	0.02	1.58	1.40	3.12	−0.01	−0.79	0.86	2.69
Per capita pers. inc.	−0.06	−1.07	−0.01	−0.02	0.17	2.38	0.35	1.59
Pct. pop white	−0.04	−0.33	0.33	1.08	0.22	1.38	0.43	2.12
Pct. under 15	−0.03	−0.26	−0.11	−0.29	−0.11	−1.11	0.93	3.60
Pct. over 65	0.01	0.08	0.04	0.11	0.12	1.23	0.33	1.52
Political ideology	0.00	−0.09	1.29	4.33	0.01	1.29	0.52	2.54
Common Factors	$\bar{y}$		$\bar{y}, \bar{X}$		$\bar{y}$		$\bar{y}, \bar{X}$	
$\varphi + \theta + \rho - 1$	0.06	7.50	−0.66	189.28	−0.36	88.34	−0.67	204.95
CD statistic	−0.62		−2.53		3.05		−0.88	
R^2	0.85		0.92		0.98		0.98	
R^2 corrected	0.85		0.92		0.98		0.98	

TABLE 14 DSLP partial derivatives, including own-source revenue: state hospital spending

Periods	Cumulative	Lower 0.10	Mean	Upper 0.10
Total effects				
0	0.036	0.017	0.036	0.055
1	0.070	0.016	0.034	0.053
2	0.103	0.015	0.033	0.050
3	0.134	0.015	0.031	0.048
4	0.164	0.014	0.029	0.046
5	0.192	0.014	0.028	0.044
47	0.700	0.000	0.005	0.015
Direct Effects				
0	0.009	−0.004	0.009	0.021
1	0.017	−0.004	0.008	0.020
2	0.025	−0.004	0.008	0.020
3	0.032	−0.004	0.007	0.019
4	0.039	−0.004	0.007	0.018
5	0.046	−0.004	0.007	0.017
47	0.178	−0.002	0.001	0.005
Indirect Effects				
0	0.028	0.008	0.028	0.047
1	0.054	0.007	0.026	0.045
2	0.079	0.007	0.025	0.043
3	0.102	0.006	0.024	0.041
4	0.124	0.006	0.022	0.039
5	0.146	0.005	0.021	0.038
47	0.522	−0.002	0.004	0.012

have a statistically significant impact. The results and implications are robust to this alternative first stage regression model that contains a spatial term.

3.6 | Revenue vs. demand effects

The results described above are unable to separate whether the increase in expenditure growth levels and growth rates is driven by a revenue effect, whereby states simply spend the additional revenue they generate via cigarette taxes on programs such as hospitals and health care, or a demand-side effect, whereby increased longevity associated with smoking cessation generates greater public health care and hospital demand. We attempt to parcel out these effects by including real total state own-source revenue collection per capita as an explanatory variable in the regression models. We include this total revenue variable in the $X_{S,t}$ matrix in Equation 2 and in the DSLP Equation 3.

We present the cigarette tax rate partial derivatives for our models with total tax collections included for health care expenditures (level) in Table 14 and for hospital expenditures (level) in Table 15.

For state hospital spending, the results are quite similar to the models in which total revenues were not included in Table 4. After controlling for total own-source revenues, the total effects short-run elasticity is 0.036 compared 0.046 in the model without total own-source revenues and the long-run elasticity is 0.700 compared to 0.789 in the model without total own-source revenue. These results suggest that only a small fraction of the increase in hospital expenditures resulting from cigarette tax rate increases occurs due to revenue effects. We conclude that most of the increase in state hospital expenditures related to cigarette taxation is due to an increased demand for public hospital usage due to greater tax-induced cigarette prices.

TABLE 15 DSLP partial derivatives, including own-source revenue: state health care spending

Periods	Cumulative	Lower 0.10	Mean	Upper 0.10
Total effects				
0	−0.006	−0.030	−0.006	0.019
1	−0.012	−0.027	−0.006	0.018
2	−0.017	−0.025	−0.005	0.017
3	−0.021	−0.023	−0.005	0.017
4	−0.025	−0.021	−0.004	0.016
5	−0.029	−0.020	−0.004	0.015
47	−0.064	−0.001	0.000	0.002
Direct effects				
0	−0.005	−0.017	−0.005	0.008
1	−0.009	−0.015	−0.004	0.007
2	−0.012	−0.014	−0.004	0.006
3	−0.015	−0.012	−0.003	0.006
4	−0.018	−0.011	−0.003	0.005
5	−0.021	−0.010	−0.003	0.004
47	−0.042	0.000	0.000	0.000
Indirect effects				
0	−0.002	−0.025	−0.002	0.022
1	−0.003	−0.023	−0.001	0.020
2	−0.004	−0.021	−0.001	0.019
3	−0.006	−0.019	−0.001	0.018
4	−0.007	−0.018	−0.001	0.016
5	−0.008	−0.016	−0.001	0.015
47	−0.022	−0.001	0.000	0.002

On the contrary, all the significant cigarette-tax-related increase in health care expenditures appears to be driven by revenue effects. All of the confidence intervals in Table 15 span zero, suggesting the variation we previously attributed to cigarette taxes is likely better explained by the overall revenue generated by the cigarette tax than the cigarette smoking-cessation induced demand for services.

Overall, we believe these results are consistent with the idea that current cigarette tax policy has long-run effects on state hospital spending, which could reflect increased longevity because of reduced smoking in the general population. These results are also consistent with Viscusi's (1995) finding that long-term health expenditures increase by $0.23 for each pack of cigarettes a smoker no longer smokes.

4 | CONCLUSIONS

Cigarette taxes reduce smoking and save lives. State policy makers may, therefore, expect that higher cigarette taxes will generate future public savings by decreasing the demands placed on future state health care services for smoking-related treatment.

However, longer life expectancy from smoking cessation and reduced smoking intensity means a greater demand for old age assistance, community health programmes, and other state health services in the long run. Additionally, the observed cigarette tax increases here may have pushed cigarette taxes above a threshold value beyond which higher taxes do not encourage existing smokers to quit, consistent with the results in Callison and Kaestner (2014a).

The overall effect indicates that higher cigarette taxes increase state health spending in the long run. We develop this evidence using data on state cigarette excise taxes and state spending on health and hospitals over the period 1960–2007. Our results come from reduced form instrumental variables (IV) models that capture the short run, contemporaneous relationship between current state cigarette excise taxes and current state spending on health and hospitals, and from dynamic spatial lag panel regression model that account for persistence in state health spending and spatial dependence in the dependent variables and explanatory variables. These models generate short run and long run estimates of the relationship between cigarette excise taxes and state health spending.

A number of excellent reasons exist for policy–makers to attempt to reduce smoking, including current reductions in smoking rates and potential future savings in terms of lower future government health or hospital spending. Tax revenue does not appear to be the driver of the increase in hospital spending, but does appear to be an important driver in the relationship we observe between cigarette tax rates and health spending. These results could reflect the specific nature of hospital spending which occurs when people are sick and need medical care, while health spending reflects general health activities, wellness programmes, regulation of air and water quality, and other programmes aimed at the general public. The results here are consistent with the idea that current cigarette tax policy has long-run effects on state hospital spending, which could reflect increased longevity because of reduced smoking in the general population. State policy makers should take this into account when considering changes to cigarette excise taxes.

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APPENDIX A

Our measure of state level health care expenditure comes from the Census Bureau's annual survey State Government Finance. We proxy for state health care spending with two state expenditure categories from State Government Finance: expenditure function code 32 (health) and expenditure function code 36 (hospitals). Both are defined in the *2006 Classification Manual* reproduced below.

A.1 | Expenditure function code 32: health spending

Definition: provision of services for the conservation and improvement of public health, other than hospital care, and financial support of other governments' health programmes.

Variable includes: expenditures for general health activities, categorical health activities and programmes, health related inspections, community health care programmes, regulation of air and water quality, rabies and animal control, and ambulance and emergency medical services only if handled separately from the local fire department. Also includes state or local expenditure financed by Federal Government "Superfund" for cleanup of hazardous waste sites. Additional examples by category are listed below.

Variable excludes: vendor payments for medical appliances, supplies, or services under public assistance programmes (use vendor payments for medical care, code E74); examination and licensing of health related professions for example, doctors and nurses (report at Protective Inspection and Regulation, NEC, code *66); operation or construction of nursing homes (report at Public Welfare, codes *77/*79); vocational rehabilitation (report at Education, codes *18/*21); coroners and crime labs (report at Police Protection, code *62).

Examples:

- General health activities: public health administration, laboratories, public education, vital statistics, research, alcohol and drug abuse prevention/rehabilitation and other general health activities.
- Categorical health activities: control of cancer, TB, socially transmitted diseases, mental illness, etc. and maternal activities funded by Federal W.I.C. funds (women, infants, and children) and child health care.
- Health related inspections: inspection of restaurants, water supplies, food handlers, nursing homes, agricultural standards or protection of agricultural products from disease.
- Community health care programmes: community and visiting nurses; immunization programs; outpatient health clinics.
- Regulation of air and water quality: sanitary engineering and other environmental activities.
- Animal control: general animal control plus rabies control, abatement of mosquitoes, rodents, and other vermin.
- Federal Government: includes the Food and Drug Administrations and the Environmental Protection Agency (with the exception of grant programmes for sewerage construction).

Special Considerations:

- Effective 1988, the Census Bureau clarified the classification of nursing homes at Public Welfare – Institutions (except inspection of such homes), code *77, and of ambulance services at Health only if such service is not organized under a fire department.
- Effective 2005, the Agriculture function was removed as a valid function in government finance surveys. Expenditure for maintaining agricultural standards or for the protection of agricultural products from disease was moved to Natural Resources, Other, code *59, rather than to this Health function.

Applicable coding options for this expenditure function	
Direct expenditure	Intergovernmental expenditure
E32 Current operations	L32 To state governments
F32 Construction	M32 To local governments
G32 Land and existing structures	
K32 Equipment (Federal, states)	
J32 Assistance and subsidies (Federal)	

A.2 | Expenditure function code 36: hospital spending

Definition: expenditures related to a government's own hospitals as well as expenditures for the provision of care in other hospitals (public or private). Own hospitals are facilities directly administered by the government, including those operated by public universities. Other expenditures cover the provision of care in other hospitals and support of other public and private hospitals. This function also covers direct payments for acquisition or construction of hospitals (whether or not the government will operate the completed facility) and payments to private corporations that lease and operate government owned hospitals.

Variable includes: hospitals include government operated general hospitals providing in-patient medical care and facilities that provide specialized care. Among the latter are: Institutions for the custody, treatment, for general care of the mentally insane, or emotionally disturbed; TB sanatoria; maternity and children hospitals; orthopedic hospitals; hospitals for chronic diseases; institutions for care and treatment of blind, deaf, developmentally disabled, or other special classes of handicap; hospitals associated with university medical schools.

Expenditures for hospitals not operated by the government include payments for the hospitalization of persons in other public or private hospitals, except payments made under public welfare programmes; financial support of other public or private hospitals, including construction; payments to private corporations who lease and operate government-owned hospitals; construction of hospitals to be leased or turned over to others to operate IF government actually supervises or controls their construction.

Variable excludes: for the Federal Government, exclude veteran's hospitals operated by U.S. Department of Veterans Affairs (report at Federal Own Hospitals — Veterans, code *37). Most other exclusions involve expenditure for care or treatment under public welfare or expenditure for specialized care that falls into another function.

The most prominent exclusions are: nursing homes (or other welfare institutions) not directly associated with a public hospital (report at Public Welfare, codes *77/*79), payments to private vendors for medical care under welfare programs (use Public Welfare — Vendor Payments for Medical Care, code E74), payments to private vendors for hospital care administered as part of public medical assistance programs (report at Public Welfare — Vendor Payments for Medical Care, code E74), payments for medical care in nursing homes or other welfare institutions unless facility is associated with a hospital (report at Public Welfare, codes *77 and *79), infirmaries serving particular institutions, like college infirmaries and prison hospitals (report at function involved), hospitals for criminally insane operated by corrections agency (report at Correctional Institutions, code *04), state schools for blind, deaf, or other handicapped primarily for education and training (report at Federal and State Other Education, code *21), payments to public hospitals by other agencies of same government (internal transfers).

Examples:

- State governments—Louisiana State University Health Sciences Center – HCSD.
- Local governments—Hurley Medical Center, Flint, Michigan (a dependent agency of the city government); King County Hospital District, state of Washington (classified as a special district government).

Special Considerations:

1. Report public hospital expenditures from Federal Medicaid funds here.
2. Effective 2005, this function includes all state and local government hospital expenditure. From 1985 to 2004, there were two hospital function codes: Hospitals–own (government operated), code *36 and other hospitals, code *38.
3. Effective with 1985 data, the following four state-only categories were consolidated into this single function due to the growing difficulty of distinguishing them: regular mental hospitals, other mental hospitals, general hospitals, and own hospitals, NEC.

Applicable coding options for this expenditure function	
Direct expenditure	**Intergovernmental expenditure**
E36 Current operations	L36 To state governments
F36 Construction	M36 To local governments
G36 Land and existing structures	
K36 Equipment (Federal, states)	
J36 Assistance and subsidies (Federal)	

A.3 | Two-stage least squares: first stage results

Table A1 establishes basic relationships in the data using panel linear regression models with state and year fixed effects. All variables are expressed in logs so that the coefficient estimates of our regressions can be interpreted as a one percent change in the independent variable resulting in a β percentage change in the dependent variable.

TABLE A1 IV results: first stage

DV is cigarette tax:	(1)	(2)	(3)
Tobacco production	−0.675	−0.794	−0.780
	−3.35	−3.96	−3.96
State Gini	10.83	8.87	8.857
	8.37	5.53	5.50
Per Capita pers. inc	–	−.875	−.8856
		−1.44	−1.46
Pct. pop white	–	1.489	1.604
		2.40	2.52
Pct. pop under 15	–	−1.616	−1.689
		−1.75	−1.82
Pct. pop over 65	–	1.392	1.41
		2.56	2.60
Politician idealogy	–	–	−.0653
			−2.29

Notes: t statistics identified below coefficient estimates. First stage identical for both dependent variables.

A.4 | Dynamic spatial lag panel results: no instrumental variables

TABLE A2 DSLP partial derivatives, no instrument: state health care spending

Periods	Cumulative impact	Lower 0.10	Mean	Upper 0.10
Total effects				
0	0.010	0.001	0.010	0.021
1	0.020	0.001	0.010	0.020
2	0.029	0.001	0.009	0.019
3	0.038	0.001	0.009	0.018
4	0.046	0.001	0.008	0.018
5	0.054	0.001	0.008	0.017
47	0.203	0.000	0.002	0.005
Direct effects				
0	−0.001	−0.007	−0.001	0.005
1	−0.002	−0.007	−0.001	0.005
2	−0.004	−0.007	−0.001	0.005
3	−0.005	−0.007	−0.001	0.004
4	−0.006	−0.007	−0.001	0.004
5	−0.007	−0.006	−0.001	0.004
47	−0.042	−0.003	−0.001	0.001
Indirect effects				
0	0.011	0.001	0.011	0.022
1	0.022	0.001	0.011	0.021
2	0.033	0.001	0.010	0.020
3	0.043	0.001	0.010	0.020
4	0.052	0.000	0.010	0.019
5	0.061	0.000	0.009	0.018
47	0.245	0.000	0.002	0.006

TABLE A3 DSLP partial derivatives, no instrument: state hospital spending

Periods	Cumulative	Lower 0.10	Mean	Upper 0.10
Total effects				
0	0.003	−0.008	0.003	0.014
1	0.006	−0.007	0.003	0.014
2	0.009	−0.007	0.003	0.013
3	0.012	−0.007	0.003	0.013
4	0.015	−0.006	0.003	0.012
5	0.017	−0.006	0.003	0.012
47	0.071	−0.001	0.001	0.003
Direct effects				
0	−0.003	−0.009	−0.003	0.003
1	−0.006	−0.008	−0.003	0.003
2	−0.008	−0.007	−0.002	0.002
3	−0.010	−0.006	−0.002	0.002
4	−0.012	−0.006	−0.002	0.002
5	−0.014	−0.005	−0.002	0.002
47	−0.025	0.000	0.000	0.000
Indirect effects				
0	0.006	−0.004	0.006	0.017
1	0.012	−0.004	0.006	0.016
2	0.017	−0.004	0.005	0.015
3	0.022	−0.004	0.005	0.014
4	0.027	−0.004	0.005	0.013
5	0.031	−0.004	0.004	0.013
47	0.096	−0.001	0.001	0.003

TABLE A4 Maximum likelihood one-period total effects with common factors, no instruments

	State hospital spending				State health care spending			
	β	T-stat	β	T-stat	β	T-stat	β	T-stat
φ	1.0	105.04	0.43	22.91	0.76	51.52	0.46	24.85
θ	−0.10	−2.65	−0.09	−2.22	−0.16	−3.80	−0.09	−2.21
ρ	0.05	1.45	0.00	0.20	0.05	1.39	0.03	−0.03
Cigarette tax	0.04	3.26	1.47	3.15	−0.00	−0.36	0.80	2.52
Per capita pers. inc.	0.056	1.12	0.02	0.06	0.34	1.71	0.32	1.52
Pct. pop white	0.05	0.43	0.31	0.98	0.42	1.10	0.44	2.152
Pct. pop under 15	−0.90	−0.89	−0.25	−0.63	−0.21	−0.86	1.00	3.81
Pct. pop over 65	−0.04	−0.58	0.07	0.22	0.33	1.34	0.32	1.55
Political ideology	0.00	0.05	1.36	4.46	0.02	1.40	0.52	2.39
Common Factors	$\bar{y}$		$\bar{y}, \bar{X}$		$\bar{y}$		$\bar{y}, \bar{X}$	
$\varphi + \theta + \rho - 1$	−0.05	7.03	−0.660	189.3	−0.349	84.74	−0.666	205.08
CD statistic	4.86		−1.356		2.890		−0.932	
R^2	0.875		0.924		0.975		0.982	
R^2 corrected	0.873		0.924		0.975		0.982	

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Resumen. Este estudio examina la relación entre los impuestos estatales sobre los cigarrillos y los gastos estatales en salud y hospitales. Se abordan dos fuentes principales de endogeneidad, procedente de (i) la relación entre los tipos impositivos y las decisiones de gasto y (ii) la dependencia espacial en las políticas de gasto debidas al uso de la producción de tabaco como instrumento para los tipos impositivos de los cigarrillos y a través de un modelo de Durbin espacial dinámico. Se estimó que la elasticidad del gasto de la tasa impositiva sobre los cigarrillos es de 0,03 (SR) y 0,87 (LR) para el gasto estatal en salud y de 0,05 (SR) y 0,79 (LR) para el gasto estatal en hospitales. Los aumentos en los impuestos sobre los cigarrillos no redujeron el gasto estatal en salud durante este período.

抄録: 本稿では、州の紙巻たばこ税と保健衛生および病院にかかる州支出の関連性を調査する。我々は、動的な空間ダービンモデルにより、1)税率と支出決定の関連性、2)タバコ製品を紙巻きタバコの税率の手段として使用する支出政策における空間依存性からの内生性の二つの主要な源を検討した。我々は、紙巻たばこ税の支出弾力性を、州の保健衛生費については0.03(SR)および0.87(LR)、州の病院にかかる支出については0.05(SR)および0.79(LR)と推定した。この期間では、紙巻たばこ税の増税による州の医療費の減少はなかった。