This paper presents a benefit-cost analysis of the ongoing, state-level tobacco prevention and control programs in the United States. Using state-level panel data for the years 1991–2007, the study applies several variants of econometric modeling approaches to estimate the state-level tobacco demand. The paper finds a statistically significant evidence of a sustained and steadily increasing long-run impact of the tobacco control program spending on cigarette demand in states. The study also shows that, if individual states follow the Best Practices funding guidelines, potential future annual benefits of the tobacco control program can be as high as 14–20 times the cost of program implementation. (JEL C2, H5, I1)

I. INTRODUCTION

State-level tobacco control programs gathered momentum in the United States during the early 1990s and have since been continuing with a varying degree of success in lowering smoking prevalence. Recently, Centers for Disease Control and Prevention (CDC) modified its 1999 guidelines with a new set of guidelines on recommended funding levels for comprehensive tobacco control programs for each state (Best Practices 2007). While states decide the annual funding levels (costs) for the control programs, assessment of the economic benefits of the programs, based on their past performance, is rarely undertaken. Unless benefits of the recommended funding levels are shown to clearly outweigh the costs of the programs, states may deviate from the CDC-recommended funding levels and divert the tobacco-related revenues away from these programs. This is, in fact, a recent trend in many states and is a concern often expressed in policy debates (American Lung Association 2009). This paper carries out a benefit-cost analysis of the ongoing, state-level tobacco control programs for the first time in light of the CDC’s Best Practices (2007) guidelines. The analysis is based on several variants of econometric approaches for modeling state-level tobacco demand, using panel data on tobacco sales from all 50 states for the period 1991–2007.

There is a large body of research that shows that state-level tobacco control programs along with federally and privately funded initiatives have played a significant role in tobacco prevention and control during the last two decades (Farrelly, Pechacek, and Chaloupka 2009).

ABBRévIATIONS

ASSIST: American Stop Smoking Intervention Study
CDC: Centers for Disease Control and Prevention
FE: Fixed Effects
IMPACT: Initiatives to Mobilize for the Prevention and Control of Tobacco Use
MSA: Master Settlement Agreement
MTF: Monitoring the Future
NCI: National Cancer Institute
NTCP: National Tobacco Control Program
OLS: Ordinary Least Squares
OSH: Office of Smoking and Health
RE: Random Effects
RWJF: Robert Wood Johnson Foundation
TUS-CPS: Tobacco Use Supplement of the Current Population Surveys
VIF: Variance Inflation Factor
Farrelly et al. 2008; Hu, Sung, and Keeler 1995b; Tauras et al. 2005). Farrelly, Pechacek, and Chaloupka (2003) investigate the joint effects of the funding level and the duration of the control program on tobacco demand and report that the longer states invest in comprehensive tobacco prevention and control programs the greater and faster the reduction in smoking. A significant amount of additional annual revenue being generated as a result of the 1998 Tobacco Master Settlement Agreement (MSA) has also opened up further opportunities to help states continue to invest in these programs. Unfortunately, in recent years funding levels for such programs have shown a steady downturn. For example, total state spending on tobacco control at 2008 prices has dropped from a high of $930.8 million in 2002 to $694.3 million in 2007. Moreover, as states face record budget deficits due to recession, many are turning to cigarette taxes to raise revenue for spending in other programs. In 2009, only North Dakota funded tobacco prevention and control programs at the level recommended by the Best Practices (2007) guidelines. Forty states and the District of Columbia spent less than 50% of the Best Practices recommended level in 2009 despite receiving millions of dollars from tobacco tax revenues and the MSA funds. Funding in the state of Washington that has been able to bring down adult smoking rate by 30% and youth smoking rate by 50% since 2002, has been reduced by half in the fiscal years 2010 and 2011 (American Lung Association 2009). This trend may adversely affect the long-run sustainability of the tobacco control efforts and the CDC’s long-term target to reduce adult smoking prevalence rate down to 10% by 2025 (Best Practices 2007).

A benefit-cost analysis of the comprehensive tobacco control programs in light of the CDC’s Best Practices (2007) guidelines involves, as a first step, a systematic assessment of the performance of the existing programs over a long time horizon. Specifically, we ask the following questions in the present research: (1) Does state-level spending on the tobacco control programs during the past two decades show any independent impact on tobacco demand? (2) If so, does this impact grow over time? The second question is more important, as it takes a long time to quit smoking and, as such, an immediate impact may not be discernable (Chaloupka and Warner 2000; Gruber 2001). Moreover, continued funding can lead to better infrastructure over time, which, in turn, can lead to increased efficiency in program delivery and evidence-based interventions, increased awareness among existing and prospective smokers. Our approach in answering the two aforementioned questions is a distinct improvement over the work of Farrelly, Pechacek, and Chaloupka (2003) in that (1) we take full advantage of the panel data structure of the state-level data by adopting the fixed- and random-effects models; (2) we model the tobacco demand recognizing that the level of control funding is endogenous in the model; (3) we model the long-run effect of the tobacco control funding as a function of elapsed time, which is the time since the initial control funding during the study period; and (4) we control for the substitution possibilities of cigarette demand by explicitly considering cigarettes available in the bordering states as a substitute good.

We extend our analysis of the two aforementioned issues further to include a benefit-cost analysis of the ongoing, state-level comprehensive tobacco control program for the first time. A benefit-cost analysis involves taking into consideration all direct and indirect costs associated with smoking. CDC (2006) reports smoking-attributable costs under three categories, namely medical costs, productivity costs, and Medicaid cost. These costs are based on numerous epidemiological and actuarial studies linking health consequences of smoking behavior. For example, CDC (2006) reports that in 2004 tobacco addiction cost the nation more than $96 billion per year in direct medical expenses as well as more than $97 billion annually in lost productivity. In 2005, the Society of Actuaries estimated that the effects of exposure to secondhand smoke cost the United States $10 billion per year. Thus, any reduction in tobacco demand can result in benefits to society in terms of costs avoided. This research draws on the reported costs in the CDC (2006) report and links it to the econometric model of tobacco demand, estimated in the paper, to further estimate the annual benefits associated with cost savings at the state level under various scenarios. The study finds a clear evidence of a sustained and steadily increasing long-run impact of the control program spending on cigarette demand. Moreover, the paper shows that the possible future benefits of the program spending along the lines of Best Practices (2007) guidelines far outweigh the cost.

The remainder of this paper is organized as follows. Section II presents a brief history of the
state-level tobacco control programs. Section III summarizes the existing literature on this issue. Section IV provides a description of the data. In Section V, we present the tobacco demand models. In Section VI, we report and analyze the empirical findings. The benefit-cost analysis is presented in Section VII. Section VIII provides the summary and conclusion.

II. A BRIEF HISTORY OF TOBACCO CONTROL PROGRAMS

There have been three major sources of revenue for the state-level tobacco control programs during the last two decades, namely the tobacco tax-generated revenue, a number of federally or privately funded initiatives, and the funds received by states through the MSA. While the funding during the 1990s was dominated by the first two sources, the MSA funds have provided a significant additional source of revenue during the 2000s.

The first major state-level initiative in comprehensive tobacco control program started in California in 1988. Massachusetts followed next in 1992. Each of these programs was funded through tax revenues generated by a sharp $0.25 per pack increase in the cigarette tax. Many other states followed the California and Massachusetts examples by raising tobacco taxes to fund similar programs in the 1990s. During the 2000s, the state of Washington raised the state excise tax by $0.60 followed by other states. More recently, the American Lung Association (2009) reports that, in 2009 14 states raised taxes to record high levels. As of August 3, 2010, the average state cigarette tax is at $1.45 a pack with New York being the highest cigarette tax state in the nation ($4.35 per pack) and Missouri being the state with the lowest tax (17 cents per pack).

Federally or privately funded initiatives started in 1991 with the American Stop Smoking Intervention Study (ASSIST) program. This was a joint initiative by the National Cancer Institute (NCI) and the American Cancer Society that supported 17 states during 1991–1998. In 1993, CDC’s Office of Smoking and Health (OSH) started supporting tobacco control activities in 32 of the remaining 33 states (excluding California) through the Initiatives to Mobilize for the Prevention and Control of Tobacco Use (IMPACT) program. In 1999, the National Tobacco Control Program (NTCP) was launched, combining the NCI and CDC initiatives into one coordinated national program funded and managed by the CDC. The CDC funding is designed to support and leverage state funding for evidence-based interventions and to help states evaluate their program efforts. Starting 1994, Robert Wood Johnson Foundation (RWJF) funded many states through its Smoke-Less States program. The program, intended to strengthen state-level tobacco control policies, initially supported 19 states but later on extended the support to 42 states.

In November 1998, the tobacco industry reached an agreement (MSA) with 46 states that sued the industry to recoup funding for Medicaid expenses for treatment of tobacco-related illnesses. Under this settlement agreement, the industry would pay $206 billion to states over a period of 20 years. The remaining four states, namely Florida, Minnesota, Mississippi, and Texas had settled with the industry separately.

The revenues from the cigarette tax and the funds from the MSA taken together have placed a substantial amount of funds at the disposal of the states, annually. In addition to MSA funds, states, such as Florida, Minnesota, Mississippi, and Texas, also have funds from previous settlements. Unfortunately, the funding levels are negligible at best compared to the total tobacco revenues. Figure 1 depicts the status of the average state tobacco control funding in 2008 dollars vis-à-vis total revenues from taxes and MSA revenues during the period under study, separately. It is disheartening to note that despite proven successes of the programs in reducing smoking prevalence, states, on average, have spent only between 0.09% (1992) and 4.5% (2002) during the study period.

In order to facilitate and strengthen the comprehensive tobacco control programs in states, CDC came up with the Best Practices guidelines for the first time in 1999 and then again in 2007 (Best Practices 2007). Best Practices (2007) is a refinement of the set of its 1999 guidelines in that it is based on evidence-based analyses of tobacco tax-funded and settlement-funded programs and published evidence of effective tobacco control strategies. Under the new guidelines, recommended per-capita annual funding ranges from $9.23

1. MSA funds were given to states as reimbursement for increased medical expenses from smoking-related diseases and were not intended to be used solely for tobacco control programs. However, access to these funds has enabled states to mobilize its revenues from other sources to tobacco control programs.
(Utah) to $18.02 (DC) with the recommended national average being $12.34. Recommended total funding ranges from $9 million (Wyoming) to $441 million (California). Unfortunately, funding by states is fast declining with average state spending being 19.4% and 17.0% in 2009 and 2010, respectively, of the CDC recommendation (Campaign for Tobacco-Free Kids 2010).

III. REVIEW OF THE CURRENT LITERATURE

The impact of spending by individual states on tobacco prevention programs has been widely studied. Interesting studies include Bauer et al. (2000); Biener, Harris, and Hamilton (2000); CDC (1999); Connolly and Robbins (1998); Hu, Sung, and Keeler (1995a, 1995b); Lightwood, Dinno, and Glantz (2008); and Pierce et al. (1998). Manley et al. (1997) provide specific focus to the ASSIST program by comparing the ASSIST states with the non-ASSIST states.

To date the only comprehensive state-level analysis that focuses on the effect of tobacco control expenditure on cigarette demand in all 50 states is by Farrelly, Pechacek, and Chaloupka (2003). The authors use annual data for the period 1981–2000 to estimate per-capita cigarette demand and adopt six econometric demand specifications, including a lagged specification for the per-capita control expenditure and a specification with cumulative per-capita control expenditure. They find statistically significant effects of state-level control funding on cigarette demand in five of the six models. The authors conduct a simulation on their estimated models and find that in the cumulative per-capita expenditure model a one-time per-capita funding increase of $6 in 1994 would lead to a 1.2% decline in per-capita cigarette sales in 2000 and a permanent increase of per-capita funding by $6 every year starting from 1994 would lead to an 8.7% decline in per-capita sales in 2000. This finding has an interesting policy implication in that sustained investments in comprehensive statewide programs may lead to faster and larger declines in smoking rates.

Tauras et al. (2005) use individual level annual survey data on youth smoking collected by the University of Michigan’s Monitoring the Future (MTF) project for the period 1991–1999 to evaluate the success of the tobacco control programs. The authors use a two-part (probit and ordinary least squares [OLS]) model and find that not only funding for tobacco control decreased youth smoking prevalence in the 1990s, but increased tobacco control funding in line with the CDC recommendation would have a substantial impact on youth smoking prevalence. Farrelly et al. (2008) links individual survey response information, obtained from the supplements to the Current Population Survey by the Bureau of Census, to the annual control expenditure by states in a logit model to study the effect of state-level tobacco programs on smoking prevalence during the period 1985–2003. They conduct a simulation similar to Farrelly, Pechacek, and Chaloupka (2003) and find that an increase in cumulative control
### TABLE 1
Data Sources

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of cigarette sales</td>
<td>State tax-paid cigarette sales, in millions of packs</td>
<td>Tax Burden on Tobacco (2008)</td>
</tr>
<tr>
<td>Price</td>
<td>Average price of cigarettes in dollars per pack in a state, inclusive of all taxes</td>
<td>Tax Burden on Tobacco (2008)</td>
</tr>
<tr>
<td>Price: bordering states</td>
<td>Average price of all the bordering states</td>
<td>Based on USA map and Tax Burden on Tobacco (2008)</td>
</tr>
<tr>
<td>Total tax</td>
<td>Average state excise tax and federal tax (in dollars) for the year per cigarette pack.</td>
<td>Tax Burden on Tobacco (2008)</td>
</tr>
<tr>
<td>Total tax: bordering states</td>
<td>Average total tax of all the bordering states</td>
<td>Based on USA map and Tax Burden on Tobacco (2008)</td>
</tr>
<tr>
<td>Total state tobacco control funding</td>
<td>Total amount of state tobacco control program funding in million dollars per year</td>
<td>ImpacTEEN.org <a href="http://www.impacteen.org/tobaccodata.htm">www.impacteen.org/tobaccodata.htm</a></td>
</tr>
<tr>
<td>Percent college graduates</td>
<td>Percentage of population 25 and older with a bachelor’s degree or more</td>
<td>U.S. Census Bureau: <a href="http://www.census.gov/popest/asrh/index.html%E2%80%94Selected">www.census.gov/popest/asrh/index.html—Selected</a> Age Groups by States</td>
</tr>
<tr>
<td>Population aged 15–24</td>
<td>Estimate for state population 15–24 years of age as of July 1st of each year</td>
<td>U.S. Census Bureau: <a href="http://www.census.gov/popest/states/asrh/index.html%E2%80%94Selected">www.census.gov/popest/states/asrh/index.html—Selected</a> Age Groups by States</td>
</tr>
<tr>
<td>Population aged 25 years or more</td>
<td>Estimate for state populations aged 25 years or more</td>
<td>Same as above</td>
</tr>
<tr>
<td>Population</td>
<td>State population estimates as of July 1st of each year</td>
<td>U.S. Census Bureau: <a href="http://www.census.gov/popest/states/asrh/index.html">www.census.gov/popest/states/asrh/index.html</a></td>
</tr>
<tr>
<td>Smoke-free air law score</td>
<td>Total score representing number of laws in place in a given year</td>
<td>ImpacTEEN.org <a href="http://www.impacteen.org/tobaccodata.htm">www.impacteen.org/tobaccodata.htm</a></td>
</tr>
<tr>
<td>Total Alciati score</td>
<td>Measures the extensiveness of state tobacco control youth access laws for a given state and year</td>
<td>ImpacTEEN.org <a href="http://www.impacteen.org/tobaccodata.htm">www.impacteen.org/tobaccodata.htm</a></td>
</tr>
</tbody>
</table>

Program expenditure is associated with a significant reduction in smoking prevalence. Marlow (2006) carries out a state-level analysis, separately for cigarette sales and for youth smoking rates across 45 states and finds little or no evidence of the effect of the tobacco control spending on cigarette sales or youth smoking. However, the Marlow study uses only 2 years of data (2001, 2002) and probably missed a lot of variability in program spending by not using a sufficiently longer time horizon and thus, the result of the study should be treated with caution.

### IV. DATA

Data for this analysis come from the U.S. Bureau of the Census, the U.S. Bureau of Labor Statistics, the Tax Burden on Tobacco study published by Orzechowski and Walker (2008), ImpacTEEN.org (http://www.impacteen.org/tobaccodata.htm), and the Tobacco Use Supplement of the Current Population Surveys (TUS-CPS). Table 1 provides the details of the data sources. The data are by state for each of the 50 states and for each year from 1991 through 2007. This provides a rectangular panel of $50 \times 17 = 850$ observations. For the purpose of analysis, all price, tax, and income data are converted from nominal to real values using constant 2008 dollars. Per-capita cigarette sales, per-capita disposable income, proportion of the population in the 15–24 age group, 25 and above age group, and the percentage of college graduates are calculated by dividing by the total state population for each state. Descriptive statistics for key
TABLE 2
Descriptive Statistics at the State Level

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observations</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cigarette sales</td>
<td>Packs sold per adult per year (q)</td>
<td>850</td>
<td>85.5</td>
<td>28.26</td>
<td>31.4</td>
</tr>
<tr>
<td>Prices, taxes, incomes, and expenditures</td>
<td>Price per pack in 2008 dollars (p)</td>
<td>850</td>
<td>3.42</td>
<td>0.96</td>
<td>1.94</td>
</tr>
<tr>
<td>Average price of all bordering states (psub)</td>
<td>850</td>
<td>3.38</td>
<td>0.89</td>
<td>2.10</td>
<td>6.24</td>
</tr>
<tr>
<td>Total tax (state + federal) per pack in 2008 dollars (tax)</td>
<td>850</td>
<td>0.96</td>
<td>0.47</td>
<td>0.32</td>
<td>3.19</td>
</tr>
<tr>
<td>Average total tax of all bordering states (taxsub)</td>
<td>850</td>
<td>0.93</td>
<td>0.38</td>
<td>0.41</td>
<td>2.48</td>
</tr>
<tr>
<td>Per-capita disposable income in 2008 dollars (pdi)</td>
<td>850</td>
<td>30,465</td>
<td>4,705</td>
<td>19,875</td>
<td>47,203</td>
</tr>
<tr>
<td>Total tobacco control program funding in millions of 2008 dollars (totfund)</td>
<td>850</td>
<td>9.87</td>
<td>21.78</td>
<td>0</td>
<td>213.73</td>
</tr>
<tr>
<td>Demographics</td>
<td>Percent college graduates (pcgr)</td>
<td>850</td>
<td>24.29</td>
<td>5.01</td>
<td>11.4</td>
</tr>
<tr>
<td>Percent age of population aged 15–24 (pc1524)</td>
<td>850</td>
<td>14.3</td>
<td>1.2</td>
<td>11.7</td>
<td>19.9</td>
</tr>
<tr>
<td>Percentage of population aged 25 or above (pc25)</td>
<td>850</td>
<td>64.61</td>
<td>2.97</td>
<td>52.35</td>
<td>71.20</td>
</tr>
<tr>
<td>Unemployment rate (unemp)</td>
<td>850</td>
<td>5.1</td>
<td>1.4</td>
<td>2.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Population (million) (popul)</td>
<td>850</td>
<td>5.51</td>
<td>6.06</td>
<td>0.46</td>
<td>36.38</td>
</tr>
</tbody>
</table>

variables are summarized in Table 2. The average price and average state tax in bordering states of a given state are calculated for each given state in the following way: first the group of all states with physical borders with the given state are identified; then a simple average of the prices and a simple average of the total (state and federal) taxes, averaged over each member state in the group, are computed.

V. TOBACCO DEMAND MODELS

A. Modeling Issues

Modeling aggregate demand for cigarettes has a long history. Interesting research in this area includes Baltagi and Levin (1985); Chaloupka and Saffer (1992); Becker, Grossman, and Murphy (1994); Sung, Hu, and Keeler (1994); Evans, Ringel, and Stech (1999); and Farrelly, Pechacek, and Chaloupka (2003). Chaloupka and Warner (2000) provide synthesis of many such papers. In the present research, we take into consideration a number of important factors discussed in the previous literature but not effectively addressed to model tobacco control funding, before specifying a tobacco demand model.

First, we apply the fixed effects (FE) and random effects (RE) estimation approaches to control for unobserved, state-specific heterogeneity. There can be numerous unobserved state-level, time-constant effects that cannot be accounted for in a standard OLS regression analysis, which make estimation of the effect of the time-varying control program expenditure biased and inconsistent.2 There may be other factors in addition to the factors discussed in footnote 2. For example, it may often be the case that high tax states are clustered, which may affect cigarette sales in these states. As the clustering phenomenon does not usually change over time, the FE and the RE models can eliminate the clustering effects (Wooldridge 2002). In short, panel data analysis with fixed or random effects can consistently estimate the effect of control program expenditure by capturing and eliminating the unobserved state-specific effects that can potentially weaken a standard OLS regression estimation.

Second, we use state-level total annual expenditure as an explanatory variable, unlike

2. There are a number of reasons for unobserved heterogeneity. Different states may have different attitudes toward tobacco usage. For example, states with a strong economic dependence on the tobacco industry (such as North Carolina, Virginia, and Kentucky) may show different cigarette sales trends. In addition, states have different laws restricting tobacco usage and different programs to encourage and support smokers trying to quit. Other state-level heterogeneity is caused by geographic location, including proximity to states with lower tax rates and access to Native American reservations and military bases where state cigarette taxes are not assessed. These factors vary among the states but tend to change slowly, if at all, over time. The models presented in the Farrelly, Pechacek, and Chaloupka (2003) study have used 50 state-specific dummies to control for fixed effects. However, in order to effectively eliminate state-level unobserved heterogeneity, in addition to the state dummies, fixed or random-effect approaches must be used for the purpose.
some earlier studies (Farrelly, Pechacek, and Chaloupka, 2003; Farrelly et al. 2008; Hu, Sung, and Keeler 1995a) that use per-capita expenditure as the explanatory variable to analyze the impact of tobacco control funding. Per-capita expenditure attaches equal weight to each population group within a state. However, population at risk differs from state to state and various population groups within a state are at varying level of risk depending on a state’s demography and prevalence of tobacco use. This means that the effect size of the control program expenditure differs across population groups within a state. Thus, a reliable estimation of the effect size requires appropriate weighting adjustment for calculation of per-capita funding level. In the absence of such weighting information it is appropriate to use total state-level funding instead of per-capita funding. Also, noting that the effect of control funding may vary from state to state depending on the size of the state, we include states’ aggregate population separately as control.3

Third, recognizing control funding as a stock variable, previous studies model cigarette demand as a function of cumulative funding level adjusted based on an arbitrary discounting factor (Farrelly, Pechacek, and Chaloupka 2003; Farrelly et al. 2008; Hu, Sung, and Keeler 1995a). We deviate from this approach and hypothesize that control program expenditure has two independent effects, namely contemporaneous effect and elapsed time effect, the latter signifying the time since the initial control program expenditure. Thus, the coefficient turns out to be significant at 1% level or better.

where \( y_{it} \) is tobacco demand, \( x_{it} \) represents the level of control funding, \( t \) denotes time elapsed in years, \( z_{it} \) represents cumulative funding up to year \( t \) (ignoring any discounting), and \( v \) represents random error.

In the case of the former formulation, the effect associated with a change in the control funding in a given year \( t \) reflects a long-run effect (contemporaneous effect: \( \alpha_1 \) and elapsed time effect: \( \alpha_2 t \)). In the case of the latter, however, the effect (\( \gamma_1 \)) of a change in the cumulative funding in a given year is constant regardless of any year. In other words, the effect (\( \gamma_1 \)) reflects the long-run effect that is averaged over the entire duration of the study period, and thus, in itself it does not account for the fact that longer investment will have greater effects. Another advantage of the “elapsed time effect” formulation, presented below, is that it avoids assumption of an arbitrary discount rate. The “elapsed time effect” and the “cumulative funding effect” formulation are discussed in more detail in the empirical section of the paper.

Fourth, controlling for the effect of cross-border sales has been an important exercise undertaken by Farrelly, Pechacek, and Chaloupka (2003) and Lovenheim (2008). However, these studies control for the incentives for making cross-border purchases/sales based on interstate price or tax differentials and population distribution. In the present research, we control for prices of cigarettes in the bordering states by

its magnitude is expected to increase over time. The reason being that infrastructure, efficiency in program delivery, quality of interventions, effectiveness of media campaigns are important features of a comprehensive tobacco control program that can only improve over time and thus, the longer states invest in these, the greater the impact.

There are two advantages of the “elapsed time effect” formulation over the “cumulative funding effect” formulation. The first relates to the fact that in the present study we are interested in the long-run impact associated with a change in the level of control funding in a given year. For example, consider the two simple formulations below:

**Elapsed time effect formulation:**

\[
y_{it} = \alpha_0 + \alpha_1 x_{it} + \alpha_2 t \cdot x_{it} + v_{it}
\]

**Cumulative effect formulation:**

\[
y_{it} = \gamma_0 + \gamma_1 z_{it} + v_{it}
\]

where \( y_{it} \) is tobacco demand, \( x_{it} \) represents the level of control funding, \( t \) denotes time elapsed in years, \( z_{it} \) represents cumulative funding up to year \( t \) (ignoring any discounting), and \( v \) represents random error.

3. As states do not allocate tobacco control funding based on its population size, controlling for population size in a state is necessary even if one uses per-capita tobacco control expenditure. This has been overlooked in some of the earlier studies cited before. This is an issue researchers and policy makers often bring out when comparing the performance of the tobacco control program in Massachusetts relative to California during the nineties (see, e.g., CDC 2005). According to them Massachusetts being a smaller state requires a higher level of per-capita tobacco control expenditure compared to California to achieve the same level of per-capita reduction in cigarette sales. As we mention in the next section, when we control for the size of the state with state’s population, the coefficient associated with per-capita tobacco control expenditure turns out statistically insignificant at any acceptable level. However, in our proposed specification, with total control funding expenditure the coefficient turns out to be significant at 1% level or better.
recognizing that cigarettes available in the bordering states serve as a substitute good.

Fifth, because of the oligopolistic structure of the tobacco market in the United States cigarette prices can be endogenous (Gruber 2001).

Endogeneity is also an issue because prices are often mis-measured (Farrelly, Pechacek, and Chaloupka 2003). Gruber (2001) notes that state-specific taxes, which is exogenous in a demand model, can capture about 80% of the variation in cigarette prices. Farrelly, Pechacek, and Chaloupka (2003) use tax instead of price in the tobacco demand model to overcome the price endogeneity problem. We specify two types of the demand—one with price as the key independent variable, which does not address the price endogeneity problem. We specify two types of the demand—one with price as the key

Finally, a state-level tobacco demand analysis the level of tobacco control funding can depend on the effectiveness of the control program in the past as well as the numerous unobserved determinants of tobacco consumption. This makes funding level endogenous in the demand model. In order to effectively address this endogeneity issue, we identify a set of appropriate instruments for the funding level and carry out a 2SLS analysis, while utilizing the panel data structure of the model.

B. Model Specification

The dependent variable in the regressions is the natural log of the quantity of per-capita tax-paid cigarette sales for each state \((q)\). The independent variables include the natural log of the real price of cigarettes per pack in dollars \((p)\), the natural log of the real (average) price per pack of cigarette in the bordering states \((psub)\), natural log of total (state + federal) real tax \((tax)\) per pack, natural log of real (average) total tax per pack in the bordering states \((taxsub)\), natural log of real per-capita personal disposable income in thousands of dollars \((pdi)\), natural log of aggregate population \((lpopul)\), and the real total annual tobacco control funding in millions of dollars \((tofund)\). As mentioned before, all dollar figures are inflation-adjusted based on 2008 prices. The socioeconomic variables that are measured in percentages are not logged. These include the percentage of college graduates \((pcgr)\), the percentage of the population between ages 15 and 24 \((pc1524)\), percentage of population aged 25 and above \((pc25)\), and the unemployment rate \((unemp)\). Finally, as is common in panel data analyses, each specification includes 16 year dummies to account for the year fixed effects. With 17 years in the panel from 50 states there are 850 data points for estimation. The econometric specifications under each estimation strategy are presented below:

2SLS specifications of the pooled OLS model:

Price-based:

\[
lq_{st} = \beta_0 + 16 \text{ year dummies} + \beta_1 lp_{st} + \beta_2 lpsub_{st} + \beta_3 lpopul_{st} + (\beta_4 + \beta_2^*t) totfund_{st} + \beta_5 lpopul_{st} + \beta_6 pcgr_{st} + \beta_7 pc1524_{st} + \beta_8 pc25_{st} + \beta_9 unemp_{st} + u_{st}
\]

Tax-based:

\[
lq_{st} = \beta_0 + 16 \text{ year dummies} + \beta_1 ltax_{st} + \beta_2 ltaxsub_{st} + \beta_3 lpopul_{st} + (\beta_4 + \beta_2^*t) \times totfund_{st} + \beta_5 lpopul_{st} + \beta_6 pcgr_{st} + \beta_7 pc1524_{st} + \beta_8 pc25_{st} + \beta_9 unemp_{st} + u_{st}
\]

2SLS specifications of the FE or RE Model:

Price-based:

\[
lq_{st} = \beta_0 + 16 \text{ year dummies} + \beta_1 lp_{st} + \beta_2 lpsub_{st} + \beta_3 lpopul_{st} + (\beta_4 + \beta_2^*t) \times totfund_{st} + \beta_5 lpopul_{st} + \beta_6 pcgr_{st} + \beta_7 pc1524_{st} + \beta_8 pc25_{st} + \beta_9 unemp_{st} + a_s + u_{st}
\]

Tax-based:

\[
lq_{st} = \beta_0 + 16 \text{ year dummies} + \beta_1 ltax_{st} + \beta_2 ltaxsub_{st} + \beta_3 lpopul_{st} + (\beta_4 + \beta_2^*t) \times totfund_{st} + \beta_5 lpopul_{st} + \beta_6 pcgr_{st} + \beta_7 pc1524_{st} + \beta_8 pc25_{st} + \beta_9 unemp_{st} + a_s + u_{st}
\]

---

4. Keeler et al. (1996) find that cigarette firms price discriminately across states and that the regulatory anti-smoking efforts are countered by cigarette firms by lowering cigarette prices. This behavior of firms can also make the price endogenous.

5. If state taxes are dependent on some unobserved determinants of the level of tobacco consumption, then tax can be endogenous. In our model, however, we assume tax to be exogenous as is done in previous research.

6. We did not use natural log of tofund, since the variable has zero values for many states in the years 1991–1993.
In each of the above models, the two suspected endogenous variables representing funding level are \( \text{totfund} \) and \( t^*\text{totfund} \). For each of the two variables, the instruments used for 2SLS estimation are: (1) “Total Smoke-Free Air Law” (\( \text{airscore} \)); (2) “Total Alciati Score” (\( \text{alciatiscore} \)); and (3) funding level in the immediately preceding year (\( \text{totfund}-1 \)). A measure of the state budget condition could be an additional instrument for the two endogenous variables, as it has been driving funding decisions in nearly all states over the past decade. However, such an instrument is not considered because of the absence of an appropriate measure of the budget condition and the lack of availability of budget-related information from states.

The \( \text{airscore} \) and \( \text{alciatiscore} \) variables are scores provided exogenously based on the number of policies in place and, as such, can be treated as truly exogenous. The details of \( \text{airscore} \) and \( \text{alciatiscore} \) are provided in the last two rows of Table 1. Further details are available in the ImpactTEEN.org website.

Each variable in the above models is observed for each state \( (s) \) and each year (elapsed time \( t = 0, 1, \ldots, 16 \)). The term \( u_{st} \) represents i.i.d. random error. The term \( \alpha_s \) represents unobserved state-specific fixed effects in the FE model that do not change over time. This unobserved fixed-effects term is assumed to be correlated with the observed explanatory variables. The term \( \alpha_t \) in the case of the RE model represents a collection of unobservable, state-specific effects that is randomly distributed and is uncorrelated with the observed explanatory variables.

7. American Lung Association publishes on an annual basis states’ performances in anti-tobacco campaign (American Lung Association 2007). Four factors by which a state’s efficacy of the control program is judged are: “tobacco prevention and control spending,” “tax rate per pack,” “smoke-free air laws,” and “youth access laws.” Grades of each state are available in this report only for the years 2003, 2004, 2006, and 2007. As exogenous instruments for current year’s control funding, we compile similar information on “smoke-free air laws” and “youth access laws” that are available for all the years in the study period and for each state from the ImpactTEEN.org website. Also, as tobacco prevention and control spending for the current year is suspected as endogenous in the demand model, we consider funding in the immediately preceding year as the third exogenous instrument explaining the efficacy of the control program. The use of lagged values of an endogenous variable as instrument in a panel model is common in the literature (see, e.g., Ziliak 1997 for an application and Cameron and Trivedi 2008 for a theoretical discussion). Finally, we did not use tax rate per pack in the immediately prior year as an exogenous instrument, since total tax in the current year (\( \text{tax} \)) is already an included exogenous variable in the three tax-based regression specifications.

In the price-based specifications we assume that cigarettes in the bordering states are substitutes for the cigarettes sold within the states and as such, the aggregate demand for cigarettes not only depends on the price of the cigarette in the state, it also depends on the average price in the bordering states. Similarly, in the tax-based specifications we assume that tax differential in the bordering states has an important effect on the state aggregate cigarette demand. Accordingly, we specify the demand for cigarette as a function of the total tax imposed within a state as well as the average tax charged in the bordering states. Both specifications can effectively control for the degree of cross-border sales in a state that are discussed in previous studies (Farrelly, Pechacek, and Chaloupka 2003; Lovenheim 2008).

Notice that the above formulation includes both contemporaneous effect (\( \beta_{41} \)) and the elapsed time effect (\( \beta_{42} t \)) of control funding. The elapsed time effect is important because, tobacco being an addictive good, behavior change is a gradual process consisting of precontemplation, contemplation, action, maintenance, and relapse (Farrelly, Pechacek, and Chaloupka 2003; Prochaska et al. 1988). Moreover, efficiency in program delivery, quality of interventions, effectiveness of media campaigns, etc., are important features of a comprehensive tobacco control program that can only improve over time.

VI. EMPIRICAL RESULTS

A. Endogeneity Issue

For the price-based pooled model, we carry out Hausman’s test for endogeneity of the two funding variable, namely \( \text{totfund} \) and \( t^*\text{totfund} \). The Hausman’s test suggests that the two variables are jointly endogenous (\( F(2, 820) = 13.96; p \text{ value } < .001 \)) and thus, demands application of 2SLS. Sargan’s score test for overidentifying restriction in the price-based pooled model fails to reject the null hypothesis of exogeneity of the set of three excluded instruments (\( \chi^2 = 0.20; p \text{ value } = .65 \)), implying that the instruments are truly exogenous.8

8. Reduced-form regression of \( \text{totfund} \) on \( \text{airscore} \), \( \text{alciatiscore} \), and \( \text{totfund}-1 \) yields an \( R^2 \) of 0.77 and the regression of \( t^*\text{totfund} \) on \( \text{airscore} \), \( \text{alciatiscore} \), and \( \text{totfund}-1 \) yields an \( R^2 \) of 0.64. Also, in the reduced form regression of \( \text{totfund} \), the only variable that is significant is \( \text{totfund}-1 \) (\( p \text{ value } < .001 \)), whereas in a reduced form regression of \( t^*\text{totfund} \) all the variables are very highly significant (\( p \text{ value } < .001 \)).
B. Issue of Spatial Autocorrelation

States differ with respect to the proportion of dollars spent on various components of the tobacco control program, which may result in spatial heterogeneity across states. For example, a high proportion spent on media advertising (particularly TV) may lead to substantial cross-border influences where media markets stretch across state borders. A spatial econometric analysis is needed to correct for such spatial heterogeneity. Unfortunately, detailed data on this are unavailable and thus, such cross-border effects remain unobserved, leading to spatially autocorrelated errors in the tobacco demand model. Although, under spatial heterogeneity parameters are still consistent, ignoring such heterogeneity may result in inefficient estimates of the demand parameters (Anselin et al. 1996; Anselin and Bera 1998).

We conduct Moran’s $I$ test to test for the presence of spatial autocorrelation for the years 1991, 1999, and 2007, separately. The years selected are the first year, middle year, and the last year of the study period. Moran’s $I$ test in our analysis involves, as a first step, finding the coordinates (latitude and longitude) of each of the 50 states. This information is available at http://www.xfront.com/us_states/. In order to facilitate the analysis, we use the coordinate of each state capital to represent the coordinate of the corresponding state. In the next step, we create a Euclidian distance from each coordinate to all the other coordinates. The third step involves creating a $50 \times 50$ weight matrix for the 50 states of which the off-diagonal entry $(i, j)$ in the matrix is equal to $1/(distance \ between \ point \ i \ and \ point \ j)$. As the first quartile Euclidian distance for the U.S. states is found to be 10.0, we attach zero weight for the states that are more than 10.0 Euclidian distance away from a given state. Finally, we compute Moran’s $I$ statistics, using the following formula:

$$I = \frac{n \sum_i \sum_j w_{ij}(q_i - \bar{q})(q_j - \bar{q})}{\left( \sum_i \sum_j w_{ij} \right) \left( \sum_k (q_k - \bar{q})^2 \right)}$$

where $w_{ij}$ are the weights, and $q_i$ and $\bar{q}$ are the per-capita cigarette demand in the state $i$ in a given year and average demand over all the $n = 50$ states in a given year, respectively. If there is no spatial autocorrelation, $I$ statistic should be close to zero. A value of $I$ statistic close to 1 indicates clustering. The third and the final steps are carried out using the STATA software specifically designed to test for spatial autocorrelation. The Moran’s $I$ statistics for the 3 years are as follows:

<table>
<thead>
<tr>
<th>Variable</th>
<th>$I$</th>
<th>$E(I)$</th>
<th>SD($I$)</th>
<th>Z-score</th>
<th>p-value</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991: $q$</td>
<td>0.229</td>
<td>−0.020</td>
<td>0.062</td>
<td>4.027</td>
<td>.000</td>
<td>50</td>
</tr>
<tr>
<td>1999: $q$</td>
<td>0.080</td>
<td>−0.020</td>
<td>0.062</td>
<td>1.611</td>
<td>.054</td>
<td>50</td>
</tr>
<tr>
<td>2007: $q$</td>
<td>0.044</td>
<td>−0.020</td>
<td>0.061</td>
<td>1.055</td>
<td>.146</td>
<td>50</td>
</tr>
</tbody>
</table>

The above tests suggests that in 1991, the null hypothesis of “no spatial autocorrelation” is rejected at any significance level; in 1999 it is rejected at 10% level; and in 2007, data do not provide any evidence of spatial autocorrelation.

Although Moran’s $I$ tests suggests that the severity of spatial autocorrelation is not a concern, there is statistical evidence of it and thus, in order to ensure parameter efficiency our estimation must be robust to spatial autocorrelation. In the following subsection, we report Driscoll and Kraay (1998) standard errors for coefficients estimates for the pooled and FE regressions. The Driscoll and Kraay (1998) approach is designed for spatially dependent panel data and the standard errors obtained using this approach are robust to general forms of cross-sectional (spatial) and temporal dependence when the time dimension becomes large, which is the case in the present analysis.

C. Estimation Results

The estimation results from the pooled, FE, and RE models are reported in Table 3, under the price-based and tax-based specifications. As discussed above, the standard errors, presented within parentheses, are all corrected for heteroscedasticity and spatial autocorrelation in the case of the pooled OLS and FE models. However, since the Driscoll and Kraay (1998) approach is not capable of correcting for spatial autocorrelation in the case of the RE model, we
TABLE 3
Coefficient Estimates for Log Cigarette Packs Sold by States

<table>
<thead>
<tr>
<th>Variable</th>
<th>Price-Based Specification (2SLS)</th>
<th>Tax-Based Specification (2SLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pooled Model</td>
<td>Fixed Effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(lp)</td>
<td>-1.53***</td>
<td>-0.91***</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>(lpsub)</td>
<td>0.30***</td>
<td>0.24***</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>(ltax)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ltaxsub)</td>
<td>-0.05***</td>
<td>-0.43***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>(lpopul)</td>
<td>0.37***</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>(lpdi)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(totfund)</td>
<td>0.0021</td>
<td>0.004***</td>
</tr>
<tr>
<td></td>
<td>(0.0015)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>(t^*totfund)</td>
<td>-0.00037***</td>
<td>-0.00044***</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0007)</td>
</tr>
<tr>
<td>(pcgr)</td>
<td>-0.021***</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>(pc)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(pc1524)</td>
<td>-0.034***</td>
<td>-0.016</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>(pc25)</td>
<td>0.027***</td>
<td>0.006***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>(unemp)</td>
<td>-0.013</td>
<td>-0.004</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Sample size</td>
<td>850</td>
<td>850</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.70</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Notes: Each equation also includes an intercept term and 16 year dummies. Numbers in parentheses are standard errors. For pooled and FE models Driscoll and Kraay (1998) standard errors with lag (4) are reported. For the RE model, heteroscedasticity-robust standard errors are reported.

**Significant at 5%; ***significant at 1%.

correct for only heteroscedasticity in the case of the RE model.9, 10

We note that in the present sample the estimated values of the error serial correlation \(\sigma_u^2/(\sigma_a^2 + \sigma_u^2)\) are: price-based models = 0.96 (FE) = 0.76 (RE); tax-based models = 0.96 (FE) = 0.81 (RE). The numerator in the expression for serial correlation represents the variation in the state-specific unobserved effects and the denominator is the total variation in the error term. This signifies that the state-specific unobserved heterogeneity accounts for a substantial portion of the variation in the residuals. Since the pooled model cannot control for the unobserved, state-specific heterogeneity, in the presence of such a high magnitude of serial correlation the results from the pooled model should be treated with caution.11

As discussed in the previous section, we present both the price-based model that does not correct for only heteroscedasticity in the case of the RE model.9, 10

11. In the presence of heteroscedasticity, Hausman’s (1978) specification test statistic to compare the FE and RE models has a non-standard limiting distribution (Wooldridge 2002) and, as such, the test result can be misleading. Despite this limitation, we carry out the specification test to compare our policy parameters associated with the variable \(t^*totfund\) in the FE and RE models. The test turns out to be inconclusive at any acceptable significance level in both price-based and tax-based specifications, indicating that either model can be used for analysis. A high serial correlation in our sample also points to the possibility that the FE parameter estimates could be close to the RE parameter estimates, which is indeed the case in the present sample, except for the control variable \(lpopul\).
not address price endogeneity and the tax-based model, which is a better model because it overcomes the problem of price endogeneity. A comparison of the parameter estimates of the three econometric approaches based on the price- and tax-based models reveals that the estimates are somewhat similar in magnitude to their respective counterpart. This signifies that addressing the price endogeneity problem in the price-based regression may not noticeably affect the parameter estimates. The coefficient on the unemployment rate variable (unemp) is insignificant in all the models. The coefficients associated with percent college graduates (pcgr) and percent population in 15–24 age group (pc1524) are insignificant in the FE model in both price-based regression as well as tax-based regression; the coefficient associated with personal disposable income per-capita (lpdi) is insignificant in both FE and RE models; and finally, the coefficient associated with total state-level tobacco control program funding (totfund) is insignificant in both price-based and tax-based pooled model. All other coefficients are significant at 10% level or better in all the models.

The variable representing percent college graduates (pcgr) proxies for the level of education in a state and the significant negative sign on its coefficient shows that the more educated the state population the less the demand for cigarette. The negative sign on the coefficient of percent population in 15–24 age group (pc1524) may be counter-intuitive. However, if one believes that during the reference period the tobacco control and prevention initiatives could target the 15–24 age group more effectively relative to other population groups in a state then this result may not be surprising. In fact, if marginal smokers in a state are assumed to be in the 15–24 age category and the population of these marginal smokers is proportional to the total population in this age group, one would expect that the benefits to society of deterring the marginal smoker are greater, on average, compared to other smokers. A similar interpretation would apply in the case of percent college graduates (pcgr), if one assumes that educated smokers are influenced on the margin. Statistical tests, however, suggest that the effect sizes associated with pcgr and pc1524 are statistically equal, signifying that whichever of the two categories is influenced on the margin, benefits to society of deterring the marginal smokers in the two categories would be statistically the same. Positive and significant coefficient on the variable representing percent population 25 or above (pc25) captures adult smokers as a subset. Thus, if the size of the adult smoking population varies directly with the total adult population and if one believes that it is harder for adult smokers to quit smoking, a positive coefficient should be expected.

The price elasticity in the price-based specification reveals some very interesting results. For example, own price elasticities show very high magnitudes ranging from $-0.91$ (FE and RE) to $-1.53$ (pooled model). However, own price elasticity can be grossly misleading as an elasticity indicator, as elasticity of cigarette demand should be based on the broadly defined market (for example, in state and out of states) not just a narrowly defined market, such as a state. According to Lovenheim (2008), who develops a model to control for cross-border sales, ignoring smuggling can cause an upward bias in price elasticity of cigarettes in absolute value. We control for cross-border sales by including average price of cigarettes in the bordering states. Our price-based regression models reveal this upward bias when one looks only at the own-price elasticity in isolation. The true price elasticity is the full price elasticity in our models and is the sum of the own- and the cross-price elasticities. For example, in the case of the price-based FE model for a 1% increase in the price within states as well as the average price of the bordering states quantity demanded decreases by 0.67% ($=-0.91 + 0.24$). In the tax-based FE and the RE models overall tax elasticity is $-0.28$ ($=-0.42 + 0.14$), which translates to price elasticity of $-0.58$. Lovenheim (2008) finds the smuggling-corrected elasticities to range between $-0.45$ and $-0.47$, which are smaller than that obtained in our price-based FE and RE models ($-0.67$) as well as that obtained in our tax-based FE and RE models ($-0.58$). Our elasticity estimates are significantly higher than $-0.32$, $-0.30$, and $-0.15$ reported by Farrell, Pechacek, and Chaloupka (2003), Evans, Ringel, and Stech (1999), and Sloan, Smith, and Taylor (2002), respectively.

Significant border price ($lpsub$) and tax elasticities ($ltaxsub$) in all the models suggest that consumers react to cigarette price or tax

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12. We run a regression of ltax on lp, all the state dummies, and all the year dummies, which yields price elasticity of tax equal to 2.06. We multiply this number to the tax elasticity of cigarette demand of $-0.28$ to arrive at the price elasticity of cigarette demand of $-0.58$. 

increases by resorting to purchase in the bordering states with lower price or tax, respectively.

The variable relating to tobacco control expenditure, namely $totfund$ that appears separately to reflect contemporaneous effect and as the interaction term to reflect elapsed time ($t \times totfund$) is the main policy variable for the present study. While the contemporaneous effect is highly significant and positive in the FE and RE models, the elapsed time effect of the control expenditure is highly significant and negative in all the models, as expected, implying that the effect of the current period’s control expenditure increases steadily over time. An analysis of the combined effect

13. A comparative analysis of our model based on total funding and the one based on per-capita funding, adopted by Farrelly, Pechacek, and Chaloupka (2003), would be a worthwhile exercise. In addition to the proposed model with $totfund$ and $t \times totfund$ as the explanatory variables, we also estimate the model based on per-capita funding. Unfortunately, a comparative analysis of the two modeling approaches could not be carried out, since, under the latter specification, the interaction coefficient associated with the per-capita funding variable turned out to be statistically insignificant in all the specifications at any acceptable level. As explained before in Section V.A, the per-capita funding measure may be inappropriate in the absence of an appropriate weighting adjustment, and thus, this finding may not be surprising.

14. Findings in the previous literature are mixed with regard to contemporaneous effect. Some studies find that state-level policies, such as advertising restrictions, health warnings, territorial restrictions, limits on youth access to tobacco products, counter advertising, etc., have positive is important to understand the role of the control programs in reducing cigarette demand. In Figure 2, we show the combined effect in reducing cigarette demand. The effects on cigarette demand reduction are shown in percentages using the three econometric modeling strategies, applied to the tax-based regression, for the period 1991 through 2008. The effect size is trending up steadily in all the models with the FE and RE models showing a high degree of agreement and the pooled model showing a relatively larger effect size. The combined effect is negative (increase in cigarette demand) up until 1998 in the case of the FE and RE models, signifying that it took 7 years after the start of the study period to realize the benefits of the control programs. This result is not surprising since, as discussed earlier, public policies to change people’s preference for addictive goods can take a long time to be effective.

In the tax-based models, the effect sizes ($\beta_{41} + \beta_{42} \times t$) for the year 1999 are: FE: 0.022%, and RE: 0.025% and those for the year 2007 are: FE: 0.308%, and RE: 0.302%. In the FE model it means, all else equal, for every one contemporaneous effect on smoking (Laugesen and Meads 1991), while others find that they have adverse effect (Baltagi and Levin 1986; Goel and Morey 1995).

15. As the study period is from 1991 ($t = 0$) to 2007 ($t = 16$), the last observation ($t = 17$) represents year 2008, which gives the out-of-sample estimate of the overall effect of control funding in 2008.
million dollar increase in control funding there is an expected reduction in per-capita cigarette sales of 0.022% and 0.308% in the years 1997 and 2007, respectively. These effects are after controlling for the year-specific fixed effect. In short, our study clearly shows that, controlling for the year-specific fixed effect, the same level of current control expenditure has larger and larger effect in reducing the per-capita cigarette sales as time passes. Our results thus fully justify our own hypothesis and reinstate the findings by Farrelly, Pechacek, and Chaloupka (2003), and the CDC’s position on this important issue, which states that “longer investment will have even greater effects” (Best Practices 2007).

As noted before, in our “elapsed time effect” formulation the effect size varies every year depending on the time elapsed \( t \), whereas in the “cumulative funding effect” formulation presented in Farrelly, Pechacek, and Chaloupka (2003) and Farrelly et al. (2008) the effect size is fixed regardless of time \( t \), which essentially reflects the average effect size over the period of 17 years. We carry out the Farrelly et al. approach with discount rates of 0%, 5%, 10%, 25%, and 50%, using both price-based models and tax-based models. We find that for discount rates of 25% and above the control funding effect is statistically insignificant. For discount rates 0%, 5%, and 10%, the effect sizes based on the tax-based FE model are: 0.034%, 0.046%, and 0.055%, respectively. The average control funding effect based on our tax-based FE model is computed as 0.040%. Thus, our estimates based on the “elapsed time effect” are comparable to those obtained from the cumulative funding approach that assumes between 0% and 5% discount.16

We also note that, as discussed before, under the “elapsed time effect” formulation the effect size associated with a change in the current year’s control funding reflects a long-run effect for that particular year. In Section VII, we take advantage of this formulation and carry out a benefit-cost analysis of the long-run effect for the year 2008 by estimating the effect size under various hypothetical levels of the control funding in the year 2008 (one year after the study period). Under the “cumulative funding effect” formulation, however, the effect of a change in the level of the year 2008 control funding reflects only an average effect over the 17 years of the study period. Thus, in itself it does not take into account the fact that longer investment will have greater effects.17

Figure 3 shows the time path of per-capita cigarette demand for the actual data as well as for the predicted values obtained from the pooled, FE, and RE models, under the tax-based specification. The time paths for FE and RE models are indistinguishable and the plot clearly shows that the predicted time paths are generally in agreement among themselves and show similar movements like the actual time path, although they are slightly but consistently lower than the actual time path.

VII. A BENEFIT-COST ANALYSIS OF THE CDC-RECOMMENDED FUNDING

We estimate the benefits (cost avoided) of smoking reduction keeping 2007 (last year of the study period) as the benchmark year and 2008 as the study year, that is the year when a hypothetical change in the control funding will be instituted and its long-run impact assessed.18

We use both the tax-based as well as the price-based specifications. In Table 4, we report the detailed results only for the FE model, under the tax-based specification. Column 1 represents various levels of additional control funding over and above the average year-2007 spending of $13.89 million (in 2008 dollars). The last value in this column represents the CDC recommended Best Practices (2007) average funding of $73.722 million (in 2008 dollars), which is $59.832 million over and above the average year-2007 spending of $13.89 million. Column 2 reports reduction in the predicted per-capita number of packs in 2008 as a result of additional funding, keeping all the other explanatory variables at their 2007 averages, including the elapsed time \( t \), which takes the

16. The results based on the discount rate approach are available with the correspondent author upon request.

17. An advantage of the “cumulative funding effect” formulation is that it follows from a relatively straightforward consumer demand model. If a new cohort of potential smokers enters every year and is influenced by antismoking funding, including a cumulative formulation may better capture the stock–flow nature of the population of smokers.

18. The “elapsed time effect” formulation proposed in the study is capable of assessing the effect of a hypothetical change in the control funding in the future. Also, since the past costs are sunk or unrecoverable, the theory of benefit-cost analysis dictates that only prospective (future) costs should be considered as relevant to an investment decision. We take advantage of the strength of our model in assessing the future and follow what the benefit-cost analysis theory dictates and carry out such an analysis for the future (year 2008).
2007 value of 16. Column 3 reports aggregate average pack reduction in a given state, obtained by multiplying column 2 by the average state population as of July 31, 2008.

The last four columns are based on Table 4 of the CDC (2006) report, which gives various costs associated with smoking, namely the medical cost per pack ($5.31), productivity cost per pack ($5.16), and Medicaid cost per pack ($1.63) in 2004 dollars.19 We first convert these figures into equivalent of 2008 dollars. We then multiply the converted figures with the aggregate average pack reduction in a given state, obtained in column 3, to arrive at the average benefits (cost avoided) of the tobacco control program in a given state.

In Table 5, we present the summary results of the aggregate benefits (cost avoided), under various levels of funding for each model. In particular, the three benefit (cost avoided) columns in the case of the tax-based specification show that if the CDC-recommended average amount of $73.722 million (which is $59.832 million over and above the average spending of $13.89 million in 2007) was spent in a given state in 2008, the estimated benefits would have ranged from $853 million (RE) to $1.0559 billion (pooled model), resulting in a net benefit in the range of, approximately, $779 million to $981 million. The same estimated net benefits figures in the case of price-based specification range from $848 million (RE) and $1.005 billion (pooled model). It is also interesting to note from the last three columns of this table that the benefit-cost ratios range from 17 to 20 in the case of the pooled model and from 14 to 17 in the FE and RE models, which means that benefits far outweigh the costs. A recent study by Lightwood, Dinno, and Glantz (2008) on California’s tobacco prevention program found that for every dollar the state spent on its tobacco control program from 1989 to 2004, the state received tens of dollars in savings in the form of sharp reductions to total healthcare costs in the state. Our study shows similar results based on the average of all the 50 states. However, our empirical model can also be used to analyze the impact of actual CDC-recommended funding for each state. In short, our empirical results show that as the

19. In response to an email inquiry, Office of Smoking and Health, Centers for Disease Control and Prevention confirmed that the three smoking-related costs are mutually exclusive.
TABLE 4  
Total Costs and Benefits under Various Levels of Control Funding (Fixed Effects Model)a

<table>
<thead>
<tr>
<th>Additional Funding in a State in 2008 (Million Dollar)</th>
<th>Predicted Per-Capita Packs Reduction in a State in 2008</th>
<th>Average Pack Reduction in a State in 2008 (Million)</th>
<th>Medical Cost Avoided (Million Dollar)</th>
<th>Productivity Cost Avoided (Million Dollar)</th>
<th>Medicaid Cost Avoided (Million Dollar)</th>
<th>Total Cost Avoided (Million Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.19</td>
<td>1.4</td>
<td>7.0</td>
<td>6.8</td>
<td>2.1</td>
<td>15.9</td>
</tr>
<tr>
<td>10</td>
<td>1.90</td>
<td>14.0</td>
<td>68.8</td>
<td>66.8</td>
<td>21.1</td>
<td>157</td>
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<tr>
<td>20</td>
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<td>27.5</td>
<td>135</td>
<td>132</td>
<td>42</td>
<td>309</td>
</tr>
<tr>
<td>50</td>
<td>8.97</td>
<td>65.1</td>
<td>324</td>
<td>314</td>
<td>99</td>
<td>737</td>
</tr>
<tr>
<td>59.832</td>
<td>10.57</td>
<td>76.5</td>
<td>382</td>
<td>371</td>
<td>117</td>
<td>869</td>
</tr>
</tbody>
</table>

aThe results are based on the tax-based specifications.

TABLE 5  
Summary of Aggregate Benefits in a State and the Benefit-Cost Ratios

<table>
<thead>
<tr>
<th>Additional Funding in 2008 (Million Dollar)</th>
<th>Total Cost Avoided (Million Dollars)</th>
<th>Benefit-Cost Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pooled Model</td>
<td>Fixed Effects</td>
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<tr>
<td>Tax-based specification</td>
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<tr>
<td>20</td>
<td>380</td>
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<tr>
<td>50</td>
<td>898</td>
<td>737</td>
</tr>
<tr>
<td>59.832</td>
<td>1,055</td>
<td>869</td>
</tr>
<tr>
<td>Price-based specification</td>
<td></td>
<td></td>
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<tr>
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<td>20.2</td>
<td>17.1</td>
</tr>
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<td>10</td>
<td>199</td>
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<td>20</td>
<td>389</td>
<td>333</td>
</tr>
<tr>
<td>50</td>
<td>919</td>
<td>792</td>
</tr>
<tr>
<td>59.832</td>
<td>1,079</td>
<td>932</td>
</tr>
</tbody>
</table>

tobacco control funding effect gathers momentum over time, benefits of a sustained level of CDC-recommended funding will grow over the years and thus, our estimates of the year 2008 benefits may well be the lower bound of the potential benefits to be accrued in all the future years.

A major limitation of the above benefit-cost analysis is that the benefits (costs avoided) associated with the smoking figures reported in the CDC (2006) report are based on studies that compare experiences of smokers as opposed to nonsmokers. It is quite likely that many of those who quit smoking as a result of successful tobacco control programs might have had other health or productivity impairments. This may pose the problem of selectivity in arriving at the reliable benefits (costs avoided) estimates. Given the absence of any other reliable benefits data at the national level, the benefit-cost analysis presented in this research can be viewed as merely an attempt to provide a perspective on the effectiveness of the tobacco control programs at the state level.

VIII. SUMMARY AND CONCLUSION

In recent years, state-level tobacco control and prevention funding in the United States has shown a declining trend. This paper presents an economic benefit-cost analysis of the ongoing, state-level tobacco control programs for the first time, which suggests that such a move by the public authorities may be short-sighted. Building on the current literature on the effect of tobacco control funding on state-level cigarette sales the study provides several methodological extensions. Using the fixed- and random-effects techniques as applied to panel data and accounting for endogeneity of the tobacco control funding level, the study models the effect of the current tobacco control funding on cigarette sales as a function of the elapsed time, which is the time since the initial control funding during
the study period. On the basis of the state-level panel data for 1991–2007, compiled from multiple sources, the study finds a statistically significant evidence of a sustained and steadily increasing long-run impact of the control program spending on cigarette demand.

Moreover, the study reveals that if the states were to follow the CDC-recommended Best Practices (2007) funding guidelines in year 2008, the aggregate benefits of the control programs, which is the sum of the cost savings associated with the medical cost, productivity cost, and Medicaid cost, could range between 14 and 20 times the average cost of implementing the tobacco control program in a state. In short, the benefits of the control programs far outweigh the costs.

REFERENCES


ImpacTEEN.org. Institute for Health Research and Policy, National Program Office, University of Illinois at Chicago.


