State-Level Tobacco Control Programs and the Demand for Cigarettes: A Retrospective Analysis Using Panel Data

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Abstract: State-level tobacco control programs in the U.S. are often funded by cigarette taxes, which are themselves an important policy tool. This study uses econometric analysis of panel data to show that the long-term impact of these taxes on cigarette sales is significantly greater than the impact arising through the effect on prices alone, and that this distinct impact increased during the 1989-2005 time period. The tax effects on demand could be caused by the funding of anti-smoking programs, signaling or alternative sources of supply. The increasing size of the tax effect gives an indication that tobacco control programs are becoming more effective at achieving their goals over time as they gain critical mass.

1. Introduction

The effect of state-level tobacco control programs on cigarette demand has been widely studied in the empirical literature.[1] Some studies use aggregated data to study the price and income elasticities of cigarette demand, while others use micro data to evaluate specific programs, such as restrictive smoke-free air laws (Tauras 2006). Use of aggregated data to estimate cigarette demand and, at the same time, evaluate the long-term performance of state-level tobacco control programs in the United States, such as anti-smoking advertising campaigns or programs to help people quit smoking, is limited. This is important since it provides a perspective as to how far the states, through their anti-smoking programs, have been able to achieve their intended goals over the years. This paper utilizes the most recent panel data from all fifty states in the U.S. to fill this gap.

The market for cigarettes in the U.S. is characterized by inelastic demand and a fairly elastic supply (Chaloupka and Warner 2000, Gallet and List 2003). This has historically helped policymakers impose taxes on cigarettes as these taxes serve as a powerful instrument not only to provide a strong incentive to reduce smoking through price increases but also to generate a substantial amount of tax revenue on a continuing basis to fund an array of tobacco control programs. In the context of aggregate demand for cigarettes, a tax is reflected through the price effect in the short run. However, the long-run effect of a tax can result in a pure tax effect that is distinct from the price effect in a number ways as described below.

Tobacco control program effect: First, and most importantly, increased funding for anti-smoking advertising campaigns or for the agencies charged with providing support to people trying to quit smoking, if effective, may reduce the demand for cigarettes in the long run. To the extent that increased cigarette tax revenues are used to fund these types of tobacco control programs there may be a negative tax effect on cigarette consumption distinct from the price effect.

[1] See Goel and Nelson (2006) for a synthesis of the literature related to this topic. An excellent summary of the research can also be found in Chaloupka and Warner (2000).

Signaling effect: As Licari and Meier (2000) suggest, governments that use excise taxes to discourage consumption, in effect, engage in more than a pure disincentive mechanism related to price. Instead, these taxes are a form of regulation of tobacco usage and the government may be sending a signal to the state residents indicating the reasons for the regulation. A long-run response to such a signal may be reduced consumption of cigarettes not merely because the prices are higher but because the government is communicating that cigarettes are detrimental to health and that people should buy fewer of them. Given the widespread publicity regarding the health effects of smoking, however, it seems rather unlikely that this signaling effect would be significant in the case of cigarette taxes in recent years.

Alternate source of supply effect: A tax increase on cigarettes may give rise to establishment of illegal markets across jurisdictional boundaries (Gruber *et al.*, 2003; Lovenheim, 2007; Stehr 2005). Although there are laws restricting the transfer of cigarettes across state borders, these laws are rarely, if ever, enforced at the individual consumer level. Thus, a smoker living in a state with high cigarette taxes may choose to travel to a nearby jurisdiction to purchase the product. This could include another state, a Native American reservation[2], a military base[3] or a duty-free shop or other international source. Mail-order shipments from these sources, which may be technically illegal, are widely available over the Internet. Moreover, some Americans are vehemently anti-tax and may choose to go out of their way to avoid paying taxes even if the total cost of the product is not different. If this is the case then these consumers may choose to travel to a lower-tax jurisdiction or pay shipping charges to a mail-order house even if the total price is the same, just for the satisfaction of knowing that they are not paying the higher tax to their state government. In short, a tax increase in a particular state can have a greater

[2] State taxes are not always applied on Native American reservations, even though some states have laws dictating that they should be applied on sales to nonresidents of the reservation.

[3] Although not everyone can access sales at a military base, those who are eligible are less likely to purchase off-base the higher the taxes are in the civilian community.

effect on sales in that state than would be reflected if there were no alternative sources of supply, and empirical studies (as described in section 2 below) have confirmed that this effect is significant.

Assessing the price effect (through a tax increase) on cigarette demand is important for assessing the short-run impact. However, policy planners may often be more interested in assessing the long-run implication of a tax policy, namely the overall impact of the state-level tobacco control programs. This requires the pure tax effect on demand to be decoupled from the price effect.[4] An econometric approach to this decoupling can be achieved by using state level panel data for a number of years. This paper explores the possibility of decoupling the pure tax effect for the first time by utilizing panel data from fifty states for the period 1989 – 2005.

Tobacco control programs have been in place in most U.S. states for several decades. Expenditures on tobacco control programs funded by cigarette taxes may require a critical mass to be effective and may take time to produce results. Thus, it is quite possible that we would see the effect of tax rates on sales to grow over time. An important policy question from a long-run perspective is this: Does the intensity of the aggregate effect of these continuing programs on cigarette demand rise or fall over the years? This important question has not been addressed in the literature. The present research systematically addresses this issue to provide an improved understanding of the effectiveness of the state-level policies governing cigarette consumption.

The present study employs three different econometric methodologies to analyze the panel data on cigarette demand, namely pooled cross-section time series, fixed effects, and random effects. Since the revenue from cigarette tax increases is often used to increase funding for tobacco control programs, we use the state tax rate as an explanatory variable to reflect the intensity of these tobacco control programs. The study finds clear evidence of a sustained, long-run impact of the control programs on cigarette demand. Moreover, the intensity of the aggregate effect of the tobacco control

[4] Farrely *et al.* (2003) investigate tax effect separately from price effect, but consider them in separate models rather than as two parts of the same model.

programs reveals an upward trend during the sample period under consideration, signifying overall success of the control programs. The results are robust across the econometric methodologies adopted.

The remainder of this paper is organized as follows. Section 2 summarizes the existing literature on the estimation of tobacco demand. Section 3 provides an overview of the data used in the analysis. Section 4 explains methodologies used in this paper. The results are presented in section 5. The strengths and weaknesses of the approaches taken are discussed in section 6. Finally, section 7 draws some conclusions from the analysis. and identifies opportunities for further research.

2. Literature Review

Many studies have looked at tobacco usage in the U.S. and have analyzed the impact of various factors on aggregate tobacco consumption. Goel and Nelson (2006) provide a synthesis of the economics literature related to this topic, while focusing on the effectiveness of anti-smoking legislation. They point out that a vast majority of studies have concentrated on price elasticity rather than tax elasticity, with the only notable exception being Baltagi and Goel (1987), who use a quasi-experimental approach to investigate the effect of taxes separately from price. Various methodologies have been used to estimate price elasticity for cigarettes, with some using aggregate consumption data and others using data on individuals. Of twenty-four studies done since 1985 using aggregate U.S. data, price elasticity estimates have ranged from -0.14 to -1.12, with a mean of -0.40; over half the studies report a number in the range of -0.30 to -0.50. Goel and Nelson also cite evidence that cigarette demand is becoming more price inelastic over time.

Another excellent summary of the research can be found in Chaloupka and Warner (2000). They also report that--in spite of variability in results and approaches--many studies find price elasticity estimates to be around -0.40. Gallet and List (2003) found 86 studies that estimate the price elasticity of cigarettes and found a mean of -0.48 with a standard deviation of 0.43, indicating a fair amount of variability. The same studies reported income elasticity averaging +0.42 with a standard deviation of 0.49.

Tauras (2006) reports a similar range in the estimates of price elasticity from various studies. Tauras' overall approach is to examine the impact of cigarette prices and smoke-free air laws on smoking. By looking at individual-level data, but controlling for state-level heterogeneity, Tauras concludes that increased cigarette prices cause a reduction in average cigarette consumption as well as the number of smokers, while more restrictive smoke-free air laws decrease the average number of cigarettes smoked by each smoker but do not affect the total number of smokers.

None of the studies exploring elasticities of cigarette demand considers decoupling the effects of prices and taxes on demand. Some research uses taxes as an instrumental variable to estimate price elasticity (e.g., Stock and Watson 2007 and Gruber *et al.* 2003). Farrely *et al.* (2003) estimate tax elasticity separately from price elasticity, but consider them in separate models rather than as two parts of the same model. Lacari and Meier (2000) consider changes in tax as a proportion of price as a signaling variable, but their focus is on the political signaling effects and not on elasticities.

Many studies have used the panel data approach. (See Baltagi *et al.* (2000) for an overview of various techniques and Stock and Watson (2007) for an example.) Others have used individual-level data (Lovenheim 2007, Farrelly and Bray 1998, Gruber *et al.* 2003, DeCicca *et al.* 2002, Farrelly *et al.* 2001, Forster and Jones 2001). The overall results are similar, but the micro data approach allows for estimation of elasticities for various subgroups of the population. The studies based on micro data show that younger people, lower-income consumers and Hispanics are more likely to reduce cigarette consumption significantly in response to price increases relative to other segments of the population.

The interactions among the cigarette tax policies of various states are explored by Sissoko (2002), Benjamin and Dougan (1997) and Baltagi *et al.* (2000), who find that elasticity estimates by individual states are very unstable. A major reason why state tax rates may be interdependent is the possibility of smuggling[5] of cigarettes across jurisdictional boundaries in order to avoid taxes. A number of authors have created models to address this issue (Lovenheim 2007, Baltagi and Levin 1986, Licari and Meier 1997, Gruber *et al.* 2003, Stehr 2005, Baltagi and Goel 1987, Coats 1995, Yurekli and Zhang 2000). Although their theoretical bases may be sound, the model used in each study is rather arbitrary and is not calibrated on empirical data. The estimates of the size of this effect vary widely due to the various theoretical models used, and also vary widely from state to state, depending on whether the state is a net importer or net exporter of bootlegged cigarettes. Coats (1995), for example, finds that 80% of the tax effects are due to cross-border sales. Lovenheim (2007) estimates that the percentage of smokers who smuggle ranges from 0% in Kentucky to 37% in Massachusetts, while over half of New Hampshire's cigarette sales go to out-of-state customers. National estimates of the total proportion of cigarettes smuggled are in the range of 3% to 6% (Thursby and Thursby 2000, Yurekli and Zhang 2000, Colburn 2008), but there is evidence from Canada (Guber *et al.* 2003) that this number can be much higher when tax differentials are significant.

Theory regarding the politics of cigarette taxation and signaling effects is provided by Licari and Meier (2000), while Gruber (2001) provides a good summary of alternative cigarette regulation strategies, including taxation. He points out that taxation on tobacco may provide positive externalities for society as a whole, and that legal agreements such as the Master Settlement Agreement with tobacco companies may be less effective than taxes, given that the agreement was only with certain producers and involved massive transfers of money to law firms rather than to the public treasury.

Tobacco supply markets, including the U.S. regulation of tobacco production quotas and pricing are covered in Womach (2003) and Capehart (2004).

3. Data

[5] also referred to in the literature as "bootlegging"

Data for this analysis came from the U.S. Bureau of the Census, the U.S. Bureau of Labor Statistics and the *Tax Burden on Tobacco* study published by Orzechowski and Walker (2005). Table 1 provides the details of the data sources. All data are by state for each of the fifty states and for each year from 1989 through 2005. All price, tax and income data are converted from nominal to real values using constant 1989 dollars. National Consumer Price Index numbers are used to adjust nominal values to real values based on 1989 dollars for all states.

Cigarette sales per adult are calculated by dividing total cigarette sales by the population age 18 and over in each state. Per capita income and the proportion of the population in the 15-to-24 age group are calculated by dividing by the total state population. Education levels are only available for alternate years, so the percentages for missing years are calculated using an average of the surrounding years. Descriptive statistics for key variables are summarized in Table 2.

4. Methodology

4.1. The three econometric approaches

We employ three different econometric techniques, namely pooled cross-section time series, fixed effects and random effects, to estimate cigarette demand at the state level. With seventeen years in the panel from fifty states there are 850 data points for estimation. We use a double log model to estimate regression coefficients that reflect elasticities of cigarette demand. The dependent variable in the regressions is the natural log of the quantity of tax-paid cigarette sales per adult per year for each state (*q*). The independent variables of primary interest include the natural log of the real price of cigarettes per pack in cents (*p*), the natural log of real per capita personal disposable income in thousands of dollars (*pdi*) and the natural log of the real state taxes rate in cents per pack of cigarettes (*tax*). The socioeconomic variables that are measured in percentages are not logged. These include the percentage of high school graduates (*school*), the percentage of college graduates (*college*), the unemployment rate (*unemp*) and the percentage of the population between ages 15 and 24 (*pop1524*).

Model-1

We specify the first model (Model-1) for the three econometric methodologies as follows:

Pooled OLS:

$$\log q_{st} = \beta_0 + \beta_1 \log p_{st} + \beta_2 \log pdi_{st} + \beta_3 \log tax_{st} + \beta_4 school_{st} + \\ \beta_5 college_{st} + \beta_6 pop1524_{st} + \beta_7 unemp_{st} + \varepsilon_{st}$$

Fixed or Random Effects:

$$\log q_{st} = \beta_0 + \beta_1 \log p_{st} + \beta_2 \log pdi_{st} + \beta_3 \log tax_{st} + \beta_4 school_{st} + \\ \beta_5 college_{st} + \beta_6 pop1524_{st} + \beta_7 unemp_{st} + a_s + \varepsilon_{st}$$

Each variable is observed for each state (*s*) and each year (*t*). The term ε_{st} .represents iid random errors. The term a_s represents unobserved state-specific fixed effects in the fixed effects model that do not change over time. This unobserved fixed-effects term is assumed to be correlated with the observed explanatory variables. The term a_s in the case of the random effects model represents unobservable state-specific effects that are randomly distributed and are uncorrelated with the observed explanatory variables.

Model-2

The long-term impact of tobacco control programs is more important than the impact in any one year, and to assess that we need to consider the behavior of aggregate demand over time as the intensity of the control program increases. Model-2 incorporates a time trend (*t*) interaction with state tax rate (*tax*) to estimate the trend in the state tax elasticity over time. Model-2 is specified as follows:

Fixed or Random Effects:

$$\log q_{st} = \beta_0 + \beta_1 \log p_{st} + \beta_2 \log pdi_{st} + \beta_3 \log tax_{st} + \beta_4 school_{st} + \\ \beta_5 college_{st} + \beta_6 pop1524_{st} + \beta_7 unemp_{st} + \beta_8 t * tax_{st} + a_s + \varepsilon_{st}$$

Model-2 is estimated using both fixed and random effects.

4.2. The problem of unobserved heterogeneity

The three Model-1 specifications above are constrained by the limited number of explanatory variables. Some of the state-specific effects are extremely difficult to observe and, if they are ignored, may cause unobserved heterogeneity in the model. There are a number of reasons for this 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.

If these unobserved effects are correlated with the observed explanatory variables, the resulting OLS estimation will be inconsistent. Fixed effects estimation is appropriate in this situation. On the other hand if these unobserved effects are random and uncorrelated with the explanatory variables, the resulting OLS estimation will be inefficient. Random effects estimation is appropriate in this situation. Fixed effect estimation is robust to the omission of any time-invariant variables and thus, produces consistent estimators. On the other hand, if the assumption of the random effects estimation is correct, random effects estimation produces estimators that are efficient. Given the unobserved heterogeneity among states, the application of fixed effects or random effects methodologies to the panel data is more apppropriate from the standpoint of econometric theory.

The fixed effects approach cannot be used effectively if the researcher's focus is on certain observed effects that do not change over time. This is not the case in the dataset under consideration in this study.[6] The random effects approach is less appealing than fixed effects for this dataset given that

[6] Even though nominal taxes often do not change from year to year--and in Mississippi and South Carolina they did not change over the entire time period of the study--the inflation-adjusted real tax rates did change every year in every state.

the observation units consist of all fifty states, and are not a random sample from a larger population. In addition, we expect that state taxes are correlated with the unobserved state-level heterogeneity. In the next section we report the results of the Hausman specification test to compare the applicability of the fixed and random effects approaches.

4.3. The issue of identification

Estimation of a demand function is frequently complicated by the structural endogeneity in price and quantity in the demand-supply interactions. Without additional structure, this problem makes the structural parameters unidentifiable (Greene 2003). Often, instrumental variable techniques are used to address this issue in econometric modeling. Unique characteristics of the cigarette supply function in the U.S. mitigate the concerns about structural endogeneity in the present analysis. Nearly all cigarettes sold in the U.S. are made using tobacco grown in the U.S. (Womach 2003). The U.S. government has implemented a strict set of production quotas and price supports for tobacco production, which are used to guarantee a market at a fixed price for all tobacco grown in the country. As a result, the companies producing cigarettes face a horizontal supply curve for tobacco, which is a major input for cigarette production. This means that the companies can buy any quantity of tobacco they need to meet production plans at a fixed price. Research has shown that other costs for cigarette producers are also essentially flat when measured on a per-pack basis, resulting in a constant-cost industry structure with no significant economies or diseconomies of scale in the relevant production range (Chaloupka and Warner 2000). Although prices of tobacco and other inputs change from year to year, at any one time the supply curve for cigarettes is essentially flat (Coats 1995). Therefore, the price-quantity combinations observed empirically over a long period of time, as in the present study, trace out the demand curve and we can use this data to identify the demand parameters without being overly concerned about the endogenous interactions of demand and supply in the model.

4.4 Expected relationships

As theory suggests, we would expect a negative price elasticity of cigarette demand. Moreover, the tobacco demand should be relatively price inelastic because cigarettes are an addictive product. Income elasticity may be either positive or negative, depending on whether cigarettes are a normal or an inferior good. At the state level, higher incomes may allow for more discretionary spending on items such as cigarettes. On the other hand, smoking has been shown to be more prevalent among lower-income consumers (Chaloupka and Warner 2000) and thus income elasticities would be pushed in a negative direction. In any case, controlling for income effects gives a more accurate estimate of the impact of prices and taxes on cigarette sales.

While price and income elasticity estimates have been addressed in numerous previous studies, decoupling the effect of taxes from the price effect on cigarette demand has not been considered in previous research. As explained before, the long-run tax effect is predominantly reflected in increased funding in tobacco control programs and thus we use state tax rate (*tax*) as a proxy measure to reflect the intensity of tobacco control programs. We would therefore expect the tax elasticity on cigarette demand to be negative.

If smoking is more common among people with less education, the expected sign of the coefficients on the percentage of college graduates (*college*) and percentage of high school graduates (*school*) would be negative (Chaloupka and Warner 2000). The sign of the coefficient for percentage of population aged 15 to 24 (*pop1524*) would depend on whether people in that age group have a higher or lower likelihood to smoke than the general population. This is the age range when many people begin to smoke, but if anti-smoking programs are effective young people may smoke less than older people, so the sign of the coefficient is difficult to predict based on theory.

Finally, the expected sign on the coefficient for the unemployment rate variable (*unemp*) might be positive since the stress of unemployment might lead to increased smoking. However, since unemployment rates probably change more rapidly than smoking rates this effect may not show up clearly in the models, which are based on annual data. The unemployment rate is also included in the model as a proxy for business cycles, as suggested by Gruber *et al.* (2003).

Previous studies have shown that young people, people with lower incomes and people with less education show more elastic cigarette demand with respect to price (Chaloupka and Warner 2000). Therefore, it is important to include these socioeconomic variables in the analysis in order to control for this type of variability between states and over time.

5. Estimation Results

Model-1

The results of the estimation for Model-1 specifications are reported in the first three columns of Table 3, separately for the pooled OLS, the fixed effects, and the random effects estimation techniques. The results for the Model-2 specifications are reported in the last two columns of Table 3, separately for the fixed effects and the random effects estimation techniques. For the pooled OLS model under the Model-1 specification, robust standard errors are used to account for the likely heteroskedasticity of the disturbance term due to unobserved heterogeneity across states.

The standard pooled OLS estimates show a price elasticity of -0.41, which is exactly in line with the consensus estimates reported in previous studies. In our analysis, however, this estimate controls for state excise taxes. This means that a price increase of 10% would cause cigarette consumption to fall by an estimated 4.1%, assuming the price increase is due to factors other than a change in state excise taxes.

The estimated coefficient for the log of real state tax is -0.16, significantly different from zero at the 1% level. This indicates that holding prices constant, a 10% increase in the state excise tax would reduce consumption by 1.6%. In other words, the model predicts that even if cigarette suppliers absorbed the entire tax increase and did not raise prices, consumption in the state would still fall after a rise in tax rates. This pure effect of tax can be explained by the factors outlined previously, namely the

(i) *tobacco control program effect*, (ii) *signaling effect*, and (iii) *alternate source of supply effect*. Thus it appears that state tax policy has an effect that is distinct from the effect that price exerts on cigarette consumption.

For the pooled OLS model the estimated income elasticity is +0.47, which is significantly different from zero at the 1% level. This would indicate that cigarettes are a normal good (a "necessity") and that a 10% increase in incomes would lead to a 4.7% increase in the quantity of cigarettes sold per adult. The consensus estimate of income elasticity based on previous studies is +0.42. This result may be biased, however, by the state-level heterogeneity which is not accounted for in the pooled OLS model.

The fixed effects and random effects methodologies do account for any unobserved state-level heterogeneity, and yield somewhat different estimates from the pooled OLS approach. Both fixed and random effects yield price elasticity estimates of about -0.32--somewhat more inelastic than the pooled OLS results--and tax elasticity estimates of -0.13, showing a slightly smaller effect of taxes on consumption after controlling for prices. All of these estimates are significantly different from zero at the 1% level.

The income elasticity estimates from the fixed and random effects methodologies are substantially different from the pooled OLS estimate and the consensus estimates based on the previous studies. The estimate using fixed effects is -0.57 and using random effects it is -0.43, both significantly different from zero at the 1% level. Thus, once accounting for state-level heterogeneity, cigarettes are shown to be an inferior good. Some individual-level cross sectional studies find a negative effect of income on cigarette demand (Wasserman *et al*. 1991, Townsend *et al*. 1994). One plausible reason is that unobserved heterogeneity often causes bias which could result in incorrect signs in the OLS estimates. The fixed and random effects estimators are capable of eliminating such bias. In the context of aggregate cigarette demand, it shows that for a given level of public funds mobilized through excise taxes for anti-smoking campaigns, states with relatively faster-growing incomes are better equipped to implement the tobacco control programs in order to ensure a faster decline in cigarette sales. The OLS model, however, shows that states with higher incomes overall sell more cigarettes per adult.

Model-2

When the interaction variable measuring how the effect of state excise tax rates on cigarette sales varies over time is added to the model the results are somewhat different. We estimated this model using both fixed and random effects methodologies. The results for both approaches are reported in Table 3, but since the Hausman test rejects the null hypothesis that the random effects model is better with a p-value of 0.007, we will focus on the results from the fixed effects regression. The Hausman test result is in line with the theoretical expectation that fixed effects are more appropriate than random effects when the sample consists of the entire population of possible observations, as is the case here.

The fixed effects estimates with the tax-time trend interaction term estimates the price elasticity of cigarette sales as -0.27, which is somewhat less elastic than estimated by the other models and by other researchers. The income elasticity is estimated at -0.21, which indicates cigarettes are an inferior good, but that changes in income have a comparatively smaller effect on cigarette sales than shown by earlier estimates. The coefficient is different from zero with a statistical significance of 5%, but not at a 1% significance level. This method estimates a base tax elasticity (β_3) of -0.068 with an estimate of time trend (β_8) of -0.0039 per year. Both of these estimates are statistically significant at the 1% level.

These results show that state cigarette excise taxes do have significant impact on cigarette consumption per adult in the state, even after controlling for overall price changes, incomes and socioeconomic variables, and that this impact has been increasing over time. Based on these estimates, the impact of taxes on consumption, holding the other variables constant, has nearly doubled during the period under study. In 1989, the base year, the estimated reduction in cigarette sales per adult due to a doubling of state excise taxes is about 7%. The time trend shows this estimate grows to about 13% by 2005.

Since the concept of including an estimate for both price elasticity and tax elasticity in the model is new in the literature, an example of how to interpret these results is in order. Consider the fixed effects model with a time interaction term for taxes. The price elasticity is estimated as -0.27 and the tax elasticity at the end of the study period is estimated at -0.13. Consider now a state with a current retail cigarette price of $4.00 per pack including a current state excise tax of $1.00. For simplicity, assume no inflation so nominal and real prices are the same. If the cigarette suppliers raise the price by $0.20, or 5%, the expected decline in sales per adult in the state would be 5 x 0.27% = 1.35%. If taxes were raised by $0.10 per pack (or 10%) to $1.10 per pack, and the cigarette suppliers absorbed the entire price increase--keeping retail prices constant--the estimated tax impact on cigarette sales per adult would be a 10 x 0.13% = 1.3% decline. Since according to our data cigarette suppliers typically raise retail prices by about twice the nominal increase in taxes[7], if taxes are raised by $0.10 per pack and retail prices rise by a total of $0.20 per pack, the overall predicted effect on sales per adult would be a decline of (5 x 0.27%) + (10 x 0.13%) = 2.65%.

The socioeconomic variables related to education, age and unemployment are included in the model primarily to control for bias in the estimates of the elasticities, but the results do show some interesting insights relating these variables to cigarette sales. The coefficient estimates for the percentage of high school graduates is small, but positive and statistically significant in all the models. This indicates that states with a greater proportion of high school graduates have slightly higher cigarette sales, which contradicts previous research that showed cigarette consumption declining with

[7] A simple regression of nominal cigarette prices on nominal state tax rates in our data set estimates a coefficient of 2.11 with a 95% confidence interval of (1.98, 2.25). This means that during the study period a one cent increase in cigarette taxes was associated with approximately a two cent increase in retail prices. Similar, though smaller, results were found by Keeler *et al.* (1996) and Coats (1995).

increased education. However, these previous results were confirmed by the negative sign on the estimated impact of the proportion of college graduates on cigarette sales. When the time trend interaction on taxes is included in the model, this estimate, while still negative, is no longer statistically significant at the 10% level.

The pooled OLS model shows that states with more young adults aged 15-24 have lower cigarette sales per adult, and that this is statistically significant at the 1% level. The fixed effects model, however, shows that once state-level unobserved heterogeneity is taken into account the effect of more young adults in a state is that cigarette sales per adult increase and this result is also statistically significant at the 1% level.

Finally, higher unemployment rates were found to have a small negative effect on cigarette sales, statistically significant in some models, but not economically significant. This indicates that business cycles do not play a key role in determining cigarette sales.

6. Strengths and Weaknesses

6.1 Strengths

The econometric methodologies used in this analysis have corroborated and extended the results of some previous research. The decoupling of tax elasticity from price elasticity provides additional insights not addressed elsewhere in the literature. In addition, the interaction of time and taxes shows that the effect of taxes on sales expands over time as tobacco control programs increase in intensity and achieve critical mass.

While some earlier studies have used panel data, not all of them took advantage of the fixed effects approach to account for state-level heterogeneity, nor was the Hausman test used to support the hypothesis that fixed effects results are more robust than the random effects results. In addition, the data used in this analysis extended the time horizon under consideration using the most recent data available.

Controls for socioeconomic variables related to age, education and unemployment, combined with the fixed effects approach, helped mitigate the potential for omitted variable bias in the estimates of elasticity.

6.2 Weaknesses

There are, however, a number of limitations of the approaches used here which should be taken into account when using the results.

For example, the dependent variable in the regressions is the log of the quantity of tax-paid cigarette sales per adult per year for each state. This is the appropriate independent variable for analysis when the goal is to understand the revenue implications of changes in state cigarette tax policies. It is not be the most appropriate variable when the goal is to understand the public health implications. In the latter case a better measure would be based on consumption rather than sales. Sales data in a state may be different from consumption data due to smuggling of cigarettes from other states, leading to overestimates of demand in states with relatively lower prices and underestimates of demand in states with relatively higher prices. Fixed effects will only account for this to the extent that this situation is unchanged over time, which is true in the case of proximity to nearby jurisdictions but not true in the case of relative pricing and taxation policies. Aggregate consumption data is much more difficult to acquire, however, and is more likely to be subject to measurement bias.

There may be additional endogeneity in the model not accounted for by the techniques used here if, for example, the assumption of horizontal supply functions is not entirely accurate. Also, by looking only at cigarette sales, the models ignore sales of non-cigarette tobacco and possible substitution effects between cigarettes and other tobacco products. Endogeneity may also exist if decisions to adjust cigarette taxes are made, at least in part, as a result of changes in cigarette sales in the state.

The use of aggregate income data may disguise the elasticity of cigarette demand by individuals, whose incomes fluctuate more widely from year to year than do aggregate incomes in a state.

The fixed effects model accounts for unobserved state-level heterogeneity whenever those effects do not change over the study period. We have assumed that other demographic variables not explicitly included in the models do not change substantially over the study period, but if some of them did the resulting estimates of elasticity may be biased.

The addictive nature of tobacco use is not explicitly accommodated by the model. We only look at short-term elasticities, but it could be likely that the effects of prices, taxes and incomes cumulate over time as smokers find it difficult to adjust smoking habits quickly in response to these economic stimuli. Lagged effects may need to be added to the model to account for this, using appropriate adjustments for serial correlation. In addition, per capita cigarette consumption is driven by two factors: the binary decision to smoke or not by each individual and then, for those who do smoke, the decision regarding the quantity of cigarettes to consume. Prices, taxes and incomes could have very different effects on these two types of decisions by consumers, and the overall sales per adult analyzed in this study cannot provide an indication of these separate effects. Restrictions on where smoking is legal may affect the consumption of those who, unrestricted, would buy more tobacco.

Finally, the existence and trend of the tax elasticity effect has been identified from the data, but the specific reasons for this effect have not been identified. Although several reasons have been hypothesized, the model does not distinguish the extent of the impact of each of them, nor if there might be other factors which cause this effect.

7. Conclusion

We have shown that cigarette taxes can be an effective part of a state-implemented tobacco control program. While previous research focuses mainly on the effect these taxes have on demand through the impact on total price, we have decoupled the price and tax elasticities and discovered that the separate tax effect is both significant and increasing during the period studied. This effect could come about through the usage of cigarette tax revenues to fund anti-smoking programs, the signaling effect and/or alternative sources of supply. Future research could expand on these results by exploring the relative contributions of each of these factors.

Increases in the tax elasticity of cigarette demand over time give an indication that state-level tobacco control programs are becoming more effective as they gain critical mass. The insights from this study should be valuable to state policymakers considering the long-term public finance and public health implications of tobacco control programs.

Table 1: Data Sources and Expected Relationships

Variable	Description	Expected relationship with dependent variable	Source
Quantity (*q*)	State tax-paid cigarette sales, in millions of packs		*Tax Burden on Tobacco* (2005), Table 10
Price (*p*)	Average price of cigarettes in cents per pack, inclusive of all taxes, per state	Negative	*Tax Burden on Tobacco* (2005), Table 13
Personal Disposable Income (*pdi*)	Total state annual personal disposable income, in thousands of dollars	Unknown	Bureau of Labor Statistics: http://www.bea.gov/regional/spi/default.cfm?satable=summary - Disposable personal income
State tax (tax)	State cigarette tax rates in cents per pack during the years-ended June 30th	Negative	*Tax Burden on Tobacco* (2005), Table 7
Per cent high school graduates (*school*)	Percentage of population 25 and older with a high school degree or more	Negative	U.S. Census Bureau: http://www.census.gov/population/www/socdemo/educ-attn.html - detailed Table 13 for each state
Per cent college graduates (*college*)	Percentage of population 25 and older with a bachelor's degree or more	Negative	U.S. Census Bureau: http://www.census.gov/population/www/socdemo/educ-attn.html - detailed Table 13 for each state
Population age 15-24 (*pop1524*)	Estimate for state populations 15 – 24 years of age as of July 1st of each year	Unknown	U.S. Census Bureau: http://www.census.gov/popest/states/asrh/index.html - Selected Age Groups by States
Unemploy-ment rate (*unemp*)	Annual unemployment rate by state	Positive	Bureau of Labor Statistics: http://www.bls.gov/data/home.htm - Labor Force Statistics from the Current Population Survey
Population age 18 or more	Estimate for state populations aged 18 or more as of July 1st of each year		U.S. Census Bureau: http://www.census.gov/popest/states/asrh/index.html - Selected Age Groups by States
Population	State population estimates as of July 1st of each year		U.S. Census Bureau: http://www.census.gov/popest/states/asrh/index.html
Consumer Price Index	National Consumer Price Indices with 1978 as base year (converted to a base year of 1989)		Bureau of Labor Statistics: http://www.bls.gov/data/home.htm - CPI-All Urban Consumers (Current Series)

Table 2: Descriptive Statistics

Variable	*Observations*	*Mean*	*Std. Dev.*	*Min*	*Max*
Cigarette sales and prices					
Packs sold per adult per year	850	120.7	36.0	42.5	250.6
Price per pack in cents (nominal)	850	235.7	94.6	103.8	568.4
Price per pack (1989 cents)	850	182.7	53.7	103.8	396.8
State tax per pack in cents (nominal)	850	37.9	33.3	2.0	246.0
State tax per pack (1989 cents)	850	29.1	22.6	1.7	162.6
Demographics					
Per cent high school graduates	850	83.1	5.5	63.2	92.8
Per cent college graduates	850	23.5	4.9	11.1	38.7
Unemployment rate	850	5.2	1.4	2.3	11.3
Per cent of population age 15-24	850	14.3	1.2	11.7	19.9
Per capita disposable income (thousands of 1989 dollars)	850	17.3	2.6	11.4	26.4

Table 3: Coefficient Estimates for Log Cigarette Packs Sold Per Adult by State

Variable	Pooled OLS (Model-1)	Fixed Effects (Model-1)	Random Effects (Model-1)	Fixed Effects (Model-2)	Random Effects (Model-2)
Log real price (*log p*)	-0.41*** (0.033)	-0.32*** (0.026)	-0.33*** (0.26)	-0.27*** (0.027)	-0.27*** (0.027)
Log real per capita disposable income (*log pdi*)	0.47*** (0.079)	-0.57*** (0.088)	-0.43*** (0.084)	-0.21** (0.10)	-0.15* (0.093)
Log real state tax (*log tax*)	-0.16*** (0.0085)	-0.13*** (0.010)	-0.13*** (0.010)	-0.068*** (0.014)	-0.080*** (0.013)
Log real state tax * time trend (*t * log tax*)	-	-	-	-0.0039*** (0.00058)	-0.0035*** (0.00055)
Percent High school graduates (*school*)	0.0036** (0.0016)	0.0076*** (0.0018)	0.0058*** (0.0017)	0.0083*** (0.0017)	0.0067*** (0.0017)
Percent college graduates (*college*)	-0.030*** (0.0021)	-0.0059*** (0.0020)	-0.0071*** (0.0020)	-0.0031 (0.0020)	-0.0048** (0.0020)
Age 15-24 percent (*pop1524*)	-0.039*** (0.0064)	0.016*** (0.0055)	0.0088* (0.0053)	0.018*** (0.0053)	0.012** (0.0053)
Unemployment rate (*unemp*)	-0.0045 (0.0051)	-0.0078** (0.0035)	-0.0060* (0.0035)	-0.0075** (0.0034)	-0.0072** (0.0034)
Sample size	850	850	850	850	850
R^2	0.64	0.77	0.77	0.78	0.78

Notes: Each equation also includes an intercept term. Numbers in parentheses are standard errors (heteroskedasticity-robust for OLS).

* Statistically significant at the 10% level.

** Statistically significant at the 5% level.

*** Statistically significant at the 1% level.

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