The Effect of Bans and Taxes on Passive Smoking

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June 2009

Abstract

This paper evaluates the effect of smoking bans in public places on the exposure to tobacco smoke of non-smokers and contrasts it with the effect of excise taxes. Exploiting data on cotinine- a metabolite of nicotine- as well as state and time variation in anti-smoking policies across US states, we show that smoking bans in public places can perversely increase the exposure of non-smokers to tobacco smoke by displacing smokers to private places where they contaminate non-smokers, and in particular young children. In contrast, we find that higher taxes are an efficient way to decrease exposure to tobacco smoke, especially for those most exposed. We supplement this analysis by showing that bans have little effect on smoking cessation, and present evidence of displacement from public places using data on time use.

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In the US, about 15 percent of the whole population smokes regularly. Yet, detectable levels of tobacco related chemicals can be found in body fluids in 70 percent of non-smokers of all ages.[1] A large medical and epidemiological literature has stressed the dangers of exposure to environmental tobacco smoke.[2] Passive smoking has been linked to a number of serious illnesses such as lung cancer or heart disease in the adult population. Passive smoking particularly affects the health of young children and babies, causing asthma, bronchitis and sudden infant death syndrome. The Environmental Protection Agency estimates that exposure to smoke causes about 200,000 lower respiratory tract infections in young children each year, resulting in 10,000 hospitalizations (Environmental Protection Agency, 1992). Medical studies consistently find that smokers impose a negative externality on non-smokers. As a result, local authorities and governments have come under pressure by the general public and by anti-tobacco groups to limit the exposure of non-smokers and generally to discourage smoking. Since the mid 1980s, support for smoking bans in public places has steadily risen. The proportion of individuals supporting a total ban in restaurants has increased from 20 percent in 1985 to 54 percent in 2005.[3] Public intervention uses two instruments to discourage smoking: directly, by limiting or banning smoking in public places, and indirectly, by raising taxes on cigarettes.

In this paper, we evaluate the effect of these policies on smokers and non-smokers and we document in particular their unintended consequences on children. We develop a model of the effect of smoking regulation on smoking, time use and passive smoking and show that smoking bans can have two distinct effects on non-smokers' exposure to tobacco smoke: they decrease exposure in public places but can lead to a perverse increase in exposure by displacing smoking towards private areas.

[1] See descriptive evidence in Appendix A.
[2] See for instance Law et al (1997), Hackshaw et al (1997), He et al (1999), Otsuka (2001), Whincup et al (2004), for adults and Strachan and Cook (1997), Gergen et al (1998), Kriz et al (2000), Lam et al (2001), Mannino et al (2001) for children who all find that exposure to passive smoke is harmful for non-smokers health.
[3] Source: Gallup poll (http://poll.gallup.com/).

To test this model, we use several sources of data describing smoking prevalence, smoking cessation, time use, and in particular, cotinine levels (a metabolite of nicotine) in body fluids. We identify the effect of anti-smoking policies with difference –in-difference and triple difference estimators using the date of implementation of these policies, spatial variation and by contrasting their effect between week-days and week-ends. These econometric techniques allow us to relax the assumption of the exogeneity of smoking bans or excise taxes.

We show that during the last two decades, bans in workplaces, bars and restaurants have led to a relative increase in the exposure of non-smokers, and in particular those who share a household with smokers. We hypothesise that such bans displace smoking to places where non-smokers are more exposed. To support these findings, we provide evidence of the effect of bans on smoking behavior and how individuals spend their time in various locations. We show that there is no clear evidence that smoking bans have a causal effect either on the prevalence of smoking or on smoking cessation and attempted quits. Using time use data, we show evidence of a displacement of smokers away from bars and restaurants when smoke free laws are passed. The evidence therefore supports the hypothesis of a displacement of smokers to places shared with non-smokers who then get more exposure to tobacco smoke.

In contrast, we find that changes in tobacco taxes have a significant effect on the exposure to environmental smoke. We find a tax-elasticity of passive smoking of about -0.2, which is higher than the tax-elasticity of cigarette consumption. The effect is particularly sizable for children who are exposed to their parents' smoke. This suggests that excise taxes are an efficient tool to curb passive smoking as smokers cut down on cigarettes smoked in the company of non-smokers, especially children.

The economic literature has focused on the effect of prices or taxes on *smokers*. Following the work of Becker and Murphy (1988), most papers estimate price elasticities both in the short and in the long run.[4] The evidence in these papers suggests that prices have an effect on cigarette consumption. However, some recent papers dispute the effect of prices. DeCicca et al (2002) show that cigarette prices do not affect initiation at young ages. Adda and Cornaglia (2006) show that although taxes affect the number of cigarette smoked, smokers compensate by smoking each cigarette more intensively. Few papers analyze the effect of bans on smoking. Among these, Evans et al. (1999) show that workplace bans decrease the prevalence of smoking for those who work.

While the literature on the effect of taxes or prices on smokers is quite large, there is hardly any evidence either on the effectiveness of these measures or on the effectiveness of restricting smoking for reducing smoking exposure among *non-smokers.*[5] [6] Yet, the debate in public circles and in the media on the effectiveness of different measures has recently intensified, and policies to ban smoking are often justified by the protection of non-smokers rather than smokers[7]. There is to our knowledge no study evaluating the response of passive smoking to the growing set of regulations and clean air Acts passed in the last decade or to changes in excise taxes[8]. One of the main reasons why there is hardly any work in the economic literature on the exposure of non-smokers to environmental smoke is the apparent difficulty of measuring passive smoking directly. By using data from bio-samples, this paper fills the gap.

[4] See for instance the paper by Becker et al (1994), Chaloupka (1991), and references in Chaloupka and Warner (2000).

[5] One exception is the effect of maternal smoking on birth weight, see for instance Rosenzweig and Schultz (1983) and Evans and Ringel (1999).

[6] The epidemiological literature has examined the issue of passive smoking, mostly from its health consequences. This literature has produced a measure of passive smoking by analyzing the concentration of cotinine, a metabolite of nicotine, in blood, saliva or urine samples. The amount of cotinine is a good marker of the exposure to environmental smoke (Jarvis et al 1984). The epidemiological literature has also tried to characterize the socio-economic groups that are more prone to exposure to environmental smoke (Pirkle et al, 1996; Howard et al, 1998; Siegel, 1993; Jarvis et al, 2001; Whitlock et al, 1998; Jarvis et al, 2000; Strachan and Cook, 1997).

[7] See for instance ASH (2005) for a summary of the case for smoke free public places.

[8] A search in EconLit for the key words "passive smoking" generates only 4 hits that are unrelated to the issue discussed here.

The remainder of the paper is structured as follows. Section I presents the theoretical framework used for analyzing the effect of passive smoke exposure, and outlines the estimation strategy. Section II evaluates the effect of anti-smoking policies on smokers and smoking cessation. Section III shows the effect of smoking bans on how smokers and non-smokers spend their time. In Section IV, we investigate the effect of different state interventions on passive smoking, measured by the cotinine concentration present in non-smokers. Finally, Section V concludes and discusses the implications of our results.

I. Methodology

This section discusses our framework for analyzing the effect of changes in smoking bans and in tax on passive smoking. In particular, we define our measure of passive smoking and describe our identification strategy.

A. A Model of Passive Smoking

To fix ideas, we present a simple model of the effect of smoking regulation on smoking and passive smoking. Suppose that a smoker derives utility from the number of cigarettes consumed, c, from another consumption good, q, from leisure either at home (T_H) or in bars (T_B), and from total smoking time (T_S). This last argument of the utility function is due to a desire to smooth cigarette consumption. Consumers derive disutility during periods of craving, when nicotine levels fall. As the time when smoking is permitted decreases, smokers are less able to smooth consumption over time, which leads to longer periods of craving. The individual's objective is to optimally choose consumption and time allocation such as:

(1) $$\max_{c,q,T_H,T_B} c^{\alpha_c} q^{\alpha_Q} T_H^{\alpha_H} T_B^{\alpha_B} T_S^{\alpha_S}$$

The utility function is increasing in all its arguments ($\alpha_i \geq 0, i = c, Q, H, B, S$). Total time during the day is the sum of time spent at home, in bars and at work: $\widetilde{T} = T_H + T_B + T_W$.

We assume that labor supply is fixed in the short run and does not change as a function of smoking bans. We denote by $T = \widetilde{T} - T_W = T_H + T_B$ the period available for leisure. Smoking time is defined as $T_S = T_H + \rho_B T_B + \rho_W T_W$, where $\rho_i \in \{0,1\}, i = B, W$ are indicators of the absence of a ban. When a ban is introduced, either at work or in bars, smoking time in that location is reduced to zero.

The agent maximizes the utility function subject to a budget constraint: $y = q + pc$, where y is income and p is the relative price of cigarettes. Optimization of this program leads to the optimal cigarette consumption and time allocation.

When no ban is in place, the optimal time spent at home is:

(2)
$$T_H^*(1) = \frac{\alpha_H}{\alpha_H + \alpha_B} T$$

When smokers cannot smoke in bars, the optimal time spent at home is:

(3)
$$T_H^*(0) = \frac{\alpha_H + \alpha_S}{\alpha_H + \alpha_B + \alpha_S} T$$

Moreover, if $\alpha_B \alpha_S > 0$, which is true given the assumption of the utility function, then $T_H^*(1) < T_H^*(0)$. Faced with a smoking ban in bars, a smoker would optimally spend more time at home.[9] The optimal number of cigarettes smoked is:

(4)
$$c^* = \frac{\alpha_c}{\alpha_c + \alpha_Q} \frac{y}{p}$$

The total consumption of cigarettes during the whole day depends only on prices and income, but not on smoking bans. Later in this section we discuss extensions of this model where bans could have an effect on overall consumption.

[9] Adda et al (2006) provides evidence that a smoking ban introduced in Scotland decreased the number of customers. Adams and Cotti (2007) show the negative effect of smoking bans on the hospitality industry in the US following smoking bans.

If smokers have a desire to smooth consumption over time, the number of cigarettes smoked at home and in bars is:

$$(5) \qquad c_H^* = c^* \frac{T_H^*(\rho_B)}{T_S(\rho_B,\rho_W)}, \qquad c_B^* = c^* \frac{\rho_B T_B^*(\rho_B)}{T_S(\rho_B,\rho_W)}, \qquad c_W^* = c^* \frac{\rho_W T_W}{T_S(\rho_B,\rho_W)}$$

The model implies that the number of cigarettes smoked at home increases when bans are in place, either in bars or at work. Note that T_W is not indexed by the existence of bans as we assume time at work as fixed.

We pointed out earlier that according to this model total consumption does not vary with bans. We can think of two extensions to this model with opposite implications. First, smokers derive utility from nicotine and not necessarily from cigarettes alone. To guard against low levels of nicotine during periods of forced abstinence due to bans, smokers may be tempted to smoke before the start of such a period. As the human body is inefficient in storing nicotine, which is constantly metabolized, smokers may have to increase consumption to compensate. This would lead to an increase in cigarette consumption following a ban. A second factor would have the opposite implication, and relies on non-separable utility over time as in Becker and Murphy (1988). Due to adjacent complementarity, a smoker would tend to decrease current consumption if future consumption is expected to be low. Hence, theory is ambiguous when predicting the effect of bans on total cigarette consumption.

Up to now we have looked at smokers' behavior. Let us now turn to non-smokers, and how their exposure to second hand smoke is affected by changes in smoking regulations.

First, consider a non-smoker who does not live with smokers. Exposure to passive smoke in this case comes solely from outside home. A ban on smoking in public places will therefore unambiguously benefit that individual. The magnitude of this effect however depends on the amount of time that non-smokers spend in workplaces and in bars.

Second, consider a non-smoker living with smokers who spends a fraction $\lambda_i, i = H, B, W$ of his time at home, bars and at work respectively. In each of these places, he is exposed to a fraction δ of each cigarette smoked by the smoker. Hence, exposure is equal to:

$$Expo = \delta(\lambda_H c_H + \lambda_B c_B + \lambda_W c_W)$$

After some simple algebra, the change in exposure resulting from a ban in bars can be expressed as:

$$\text{(6)} \qquad \Delta Expo^{Work} = \frac{\delta c^*}{\alpha_H + \alpha_B} \frac{T_W}{\tilde{T}} \left[\alpha_H (\lambda_H - \lambda_W) + \alpha_B (\lambda_B - \lambda_W)\right]$$

The effect of the ban on non-smokers is ambiguous and depends on the time spent at home, bars and work. Non-smokers who do not spend time at work (e.g. children) see an increase in exposure. For individuals who work, the effect is ambiguous and depends on the relative time spent at different locations.

The effect of smoking bans in bars is more complicated as smokers also adjust their time use. The change in exposure can be written as:

$$\text{(7)} \qquad \Delta Expo^{Bars} = \frac{\delta c^* T \alpha_B}{A} \big[T(\alpha_H + \alpha_S)(\lambda_H - \lambda_B) + T_W(\alpha_S \lambda_H - (\alpha_H + \alpha_B + \alpha_S)\lambda_B + (\alpha_H + \alpha_B)\lambda_W\big]$$

where A is a positive coefficient. For individuals who do not spend any time in bars, the ban results in an increase in exposure. For all others, the effect is ambiguous and depends on the relative amount of time spent in bars, as bans reduce the direct exposure to tobacco smoke in this location.

Smoking can also be regulated through higher cigarette prices. If prices are increased by a factor $\gamma > 1$, the change in exposure for non smokers (living with a smoker) can be written as:

(8) $$\Delta Expo = -\frac{\delta}{T_S}\frac{\alpha_C}{\alpha_C+\alpha_Q}\frac{\gamma-1}{\gamma}\frac{y}{p}\left(\lambda_H T_{H+}\lambda_B T_{B+}\lambda_W T_W\right)$$

Changes in excise taxes have an unambiguous effect on exposure. It is also straightforward to show that the effect of taxes is larger for non-smokers living with smokers than for those who do not.

The model shows that it is not straightforward to infer the effect of government interventions on *non-smokers* by looking at the effect of these interventions on *smokers* (i.e. measuring the change in prevalence, or the change in the number of cigarettes smoked). Therefore, an empirical analysis should measure passive smoking *directly* in non-smokers.

In summary, the model has four implications, which we test using a variety of data on smoking behavior, time use and data on exposure to tobacco smoke. First, the model indicates that cigarette consumption should not be affected by the introduction of anti-smoking policies. Second, smoking bans in bars and restaurants should lead to a displacement of smoking and smokers towards home. Third, workplace bans are likely to lead to an increase exposure to tobacco smoke for children. This is also the case for bans in bars and restaurants provided that children do not spend much time in such locations. Finally, excise taxes should decrease exposure.

B. Econometric Specification

In the empirical part of the paper, we test several predictions of our model. We investigate the effect of anti-smoking policies along three dimensions. First, we analyze the direct effect on smokers to test whether these policies lead to smoking cessation or reduced consumption. Second, we investigate the effect of smoking bans on time use and time spent with children. Finally, using data on cotinine in biological samples, we look for an effect of anti-smoking policies on non-smokers.

We regress these outcome variables on anti-smoking policies, using the following model:

(9) $$S_{ist} = \beta_w B_{st}^{w} + \beta_{go} B_{st}^{go} + \beta_T \log Tax_{st} + X_i \gamma + \lambda(s,t) + \varepsilon_{ist}$$

where S_{ist} is a measure of smoking for individual i in state s and in period t, and B_{st}^{w}, B_{st}^{go} are the percentages of individuals in a given state and year that are subject to a full ban at work and in bars and restaurants ("Going Out"). We also relate smoking to (log) excise taxes, Tax_{st}, to individual characteristics, X_i, as well as to state specific characteristics denoted by $\lambda(s,t)$. These include a state indicator, lagged state log GDP, and trends. Depending on the time length and the structure of the data set, we include either a set of aggregate time dummies, or region or state specific trends.[10]

The identification of the effect of regulation and taxes comes from variation across states and time, and not from cross-sectional differences in the level of state regulations or taxes, which are taken into account by state dummies. Our identification relies on the exogeneity of *changes* in taxes and regulation *within* states, net of time trends, but not on the heterogeneity in levels of regulations and exposure to passive smoking.

When we use cotinine data as a dependent variable the data set is shorter than the data on smoking behavior and does not support state trends. In an attempt to rectify this, as detailed below in Section IV, we include an aggregate time indicator as well as regional time trends. There may be some concerns that regional time trends do not fully capture variables that could be correlated both with passive exposure and the introduction of anti-smoking policies at state level. The way we address this concern is by enriching the model with time varying state characteristics. We use lagged smoking prevalence rate and cessation rate at state level. Tougher smoking regulations may be introduced in states where the prevalence of smoking is

[10] In equation (9) we do not control explicitly for cross-border effects, which would require the inclusion of taxes in cheaper states, such as those which produce tobacco. Provided that the shipping costs of cigarettes in the US are similar across states, which is the case with the rise of internet sales, the omitted tax is the same as a time fixed effect. Hence, in our specification, aggregate time dummies capture cross-border effects.

decreasing as they would be politically easier to implement if the median voter shifted towards a non-smoker. Another possibility is that tougher regulations are more likely to be enforced on health grounds in states where smoking is on the increase, or increasing relative to the rest of the country. Prevalence and cessation rates are key variables used to monitor smoking trends in relation to health issues and are easily observable by policy regulators.

In addition, in Section IV.E, we relax the assumption of the exogeneity of taxes and smoking bans and show that we can consistently identify a subset of the parameters of interest which characterize displacement effects.

The model is estimated by OLS, and standard errors are adjusted for heteroskedasticity and clustered at state level. This correction accounts for the presence of a common random effect at the state level. We therefore allow for serial correlation in the error term following Bertrand et al (2004) who show that difference-in-difference estimations can be seriously biased in the presence of autocorrelation. All regressions are weighted using the weights provided in the particular surveys to make the samples representative of the US population. This is important to make results comparable across different sections of the paper, as some surveys over-sample specific groups of the population.

C. History of Smoking Bans and Data

Widespread smoking bans and smoking restrictions are a relatively novel phenomenon in the United States. Some attempts to ban smoking and the sales of cigarettes, on the grounds of moral concern, were made during the prohibition in the 1920s where 15 states banned cigarette sales. However, these laws were repealed by the end of that decade. Half a century later, as research progressively made clear the effect of tobacco smoke, new efforts to ban smoking emerged. The first smoking bans to be introduced in the United States were in place in Minnesota in the mid-1970s. They required restaurants to have a non smoking section, while exempting bars. During the 1970s and the 1980s, smoking bans were progressively imposed, usually by requiring separate areas for smokers and non smokers, as in airlines in 1973. During the 1990s, smoking bans became more stringent, with the imposition of total bans in workplaces, public places, restaurants and bars. These were pioneered by municipalities and counties, mainly in California in the early 1990s. The first states to impose such a ban were California and Utah with 100 percent smoke-free restaurants in 1995. An important point to note is that smoking bans are often introduced locally, at city or county level. These bans may conflict with preemption laws at state level, which prevent local communities from enacting local ordinances that are more stringent than the one defined at state level. These preemption laws have provided a way for tobacco firms to oppose smoking bans.

Data on smoking bans are obtained from the American Non Smokers' Rights Foundation, which collected the date of introduction of smoking bans, whether these were introduced at city, county or state level.[11] All the dates pertain to the introduction of 100 percent smoke free laws in workplaces, bars and restaurants where no pre-emption laws are in effect. Hence, we do not take into consideration policies that attempt to restrict smoking by designating special areas to smokers or non-smokers. Although these policies may prevent some exposure to tobacco smoke, there is a problem of enforcement. Second, they may have a lower effect on smoking behavior as they do not impose a heavy cost on smokers.

We combine smoking bans for bars and restaurants by taking the date after which there is a complete ban in both bars and restaurants in a particular geographical location. We do so, because the distinction between bars and restaurants can be sometimes artificial and because we anticipate that bans in only one place may just displace smokers from one establishment to the other, with little overall effect.

We aggregate the bans at state level, by computing the percentage of the population in any year that is covered by a full ban at work, or in bars and restaurants, using the population of cities, counties or states at the time of the ban.

[11] The data is available at *www.no-smoke.org/pdf/Effective**Population**List.pdf*

We merge to these data information on state level excise taxes. The data comes from the Tax Burden on Tobacco, published by The Tobacco Institute until 1998 and updated by Orzechowski and Walker (2001). It reports taxes by state and year. We deflate taxes using the consumer price index. Figure 1 plots the time trend of these policies at a national level.

[Figure 1]

Excise taxes have risen from around 30 cents per pack in the late 1980s to more than 80 cents in 2006, with a sharp rise from 2001 onwards (prices in 2000 dollars). Hardly any bans were in place before the mid 1990s, but in 2006, about 40 percent of the population was living in an area with a smoking ban in workplaces or with smoking bans in bars and restaurants. Of course, there are large differences across time and states, which we exploit in our empirical analysis. [12]

II. Effect of Bans and Taxes on Smokers

A. Data and Descriptive Statistics

We start the empirical analysis by investigating the effect of anti-smoking policies on smokers and smoking behavior. Previous results have used cross-sectional analysis or time series data to investigate their impact. Levy and Friend (2003) and Eriksen and Cerak (2008) survey this literature, which finds an effect of regulation on smoking rates. In contrast, we use repeated cross-sectional data and control for time and geographical effects.

[12] Much of the rise in the prevalence of bans in bars and restaurants is due to California, which imposed a state-wide ban in 1995 in restaurants and in 1998 in bars. However, California is not the only state with bans, and if we exclude this state, the population covered by bans is more than 30 percent in 2006.

We use data from the Behavioral Risk Factor Surveyance System (BRFSS), which collects data on health risk behavior. This is the most comprehensive data on smoking behavior and is used to monitor smoking trends at state level. Approximately 140,000 individuals aged 18 or older are surveyed every year. The data set starts in 1984 and runs through to 2006.[13] We also use data on adult per capita sales of cigarettes by state, between 1970 and 2007 to investigate the effect of anti-smoking measures on the quantity smoked.[14]

We focus on four different measures: smoking prevalence, the percentage of former smokers, attempted quits, and the number of cigarettes purchased per day. Smoking prevalence is a stock measure, which depends both on initiation and quits. The second outcome measures the percentage of former smokers among "ever smokers" and provides sharper information on the effects of anti-smoking policies on quits. Our third measure, attempted quits, is a flow variable measuring the proportion of smokers who have attempted to quit smoking within the last 12 months of the survey. One can conjecture that this outcome is able to detect in a more precise way any effect of policy variables.

[Figure 2]

Figure 2 displays the trends in smoking behavior for all available years. Smoking prevalence decreased over the sample period, from about 29 percent to 19 percent. The proportion of former smokers increased from 43 percent to 55 percent during the same period. Attempted quits present a hump-shaped pattern, decreasing from 60 percent in 1990 to 44 percent in 1995, and then increasing to 57 percent in 2006. Cigarette sales decreased from a peak at seven cigarettes per day to about three per day in 2007.

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[13] Appendix A1 provides more details on the data set.

[14] We refer the reader to Appendix A1 for more information on the data. For this outcome, the regressions are done at state level, using population weights.

B. Results

Table 1 presents the results obtained using the four different measures discussed above. We display two sets of results for each smoking measure, either including aggregate time indicators or state specific linear trends. The first column indicates that an increase in smoking bans in workplaces from zero to 100 percent of the population increases the prevalence of smoking by 0.2 percentage points. However, this number is not significantly different from zero. In contrast, we find evidence of an effect of smoking bans in bars and restaurants. A total ban leads to a decrease in prevalence of about two percentage points. Similarly, a 100 percent increase in the state tax reduces the prevalence of smoking by about 0.7 percentage points.

[Table 1]

These estimates are obtained with state fixed effects as well as with aggregate time indicators. Given that our data set covers up to 22 years of data per state, it is quite possible that the regression leaves out some state specific trends which are correlated with smoking bans and excise taxes. In column (2), we therefore add state specific linear trends to capture unobserved trends which may be correlated with both anti-smoking policies and changes in smoking behavior. [15] When controlling for state specific trends neither smoking bans in bars and restaurants nor taxes have a significant effect on smoking prevalence.

Columns (3) and (4) display the effect of these policies on the percentage of former smokers. As for smoking prevalence, we do not find any evidence that smoking bans in workplaces lead to a change in smoking behavior. For smoking bans in bars and restaurants, we get conflicting results, with an increase in quitting when we use aggregate time indicators and a decrease in quitting when we control for state specific trends. This

[15] This is also motivated by the fact that placebo regressions leading the policy variables forwards appear to pick up spurious effect when we only use an aggregate trend. See Appendix B.

result indicates that anti-smoking policies are confounded by trends at state level. Finally, excise taxes appear to increase quitting, although the effect is not significant once state linear trends are introduced.

Column (5) shows the effect on attempted quits within the last twelve months, when we include aggregate time indicators. There is no evidence of an effect of smoking bans on attempted quits. On the other hand, higher taxes lead to an increase in attempted quits. Column (6) displays the results with state specific trends. It should be noted that the placebo results for this particular outcome in Table A 1 do not show spurious findings with aggregate time indicators, while with state specific trends, we find weak spurious evidence. This could be a sign of over-fitting when using state specific trends. Note as well that the time span is shorter than for the two previous outcome variables, ranging from 1990 only to 2006. Nevertheless, column (6) in Table 1 shows that tighter bans do not lead to a significant increase in attempted quits.

The last two columns of Table 1 show the effect of anti-smoking policies on cigarette sales, expressed as the adult per capita consumption per day. When including an aggregate trend in the model, we find no significant effect of workplace bans, but a significant decrease of a quarter of cigarettes per day for bans in bars and restaurants. Doubling excise taxes lead to a decrease of one cigarette per day. Given the time span of the data (thirty eight years), an aggregate time trend will certainly not be enough to purge the model from the effect of omitted variables, such as anti-smoking sentiments or attitudes towards health. This can be seen in Table A 1, where placebo results are displayed. The regression finds spurious and large effects of bans in bars and restaurants, as well as for excise taxes. In contrast, the spurious results disappear when we include state specific trends in the model. Column (8) displays the results when state specific linear trends are added to the model. We do not find evidence of a significant decrease in the number of cigarettes consumed when introducing smoking bans (we even find evidence of an increase for bans in bars and restaurants, but this result is only significant at the 10% level). We find a negative effect of taxes on cigarette sales, which implies an elasticity of -0.13, which can be considered as a benchmark for the effect on non-smokers, which we present later.

In summary, we do not find evidence that smoking bans, either in workplaces or in bars and restaurants, have an effect on smoking behavior, in terms of consumption and smoking cessation. These results are not surprising given that the model has no firm predictions regarding these outcomes.

III. Smoking Bans and Time Use

In Section I.A, we show that our model predicts that smoking bans lead to a change in the way individuals spend their time in public and private places. In this section, we provide evidence on how much time individuals, including children, spend in places affected by smoking bans. We then investigate whether bans, and in particular those in bars and restaurants, induce a change in the amount of time individuals spend in different locations and with whom they are. This is important to understand the possible channels of passive smoking that we are investigating in section IV.

A. Data and Descriptive Statistics

The data is drawn from the American Time Use Survey covering the period 2003 to 2006. In addition, we use the National Human Activity Pattern Survey of time use which covers the period 1992 to 1994, although with a reduced sample size. Both surveys have a similar structure. The survey includes individuals aged 18 and above. Each individual is asked to fill in a diary of the previous day with all primary occupations and locations. For each of the declared activities, the respondent was asked whether children were present at the time of the activity. A more detailed description of the data set can be found in Appendix A2.

For the purpose of our analysis, we group the locations into three main categories, “home”, which include time at home (including outside occupation in a backyard and time at other’s homes), restaurants and bars, and all other locations, which include work, travel, or shopping.

The survey includes some demographic characteristics such as age, sex, race, years of education, state of residence and the presence of children. In two periods, 1992 and 2003, the survey also includes information on smoking status. The survey provides weights to make the sample representative of the US population, which are used to compute all our results. This makes the results for the use of time comparable to the one on smoking behavior presented in the previous section.

Table 2 displays descriptive statistics of the data. On average, an individual spends about 17 hours per day at “home”, about 25 minutes in bars and restaurants and seven hours elsewhere (column one). If we only look at smokers (column 2), they spend almost twice as much time in bars and restaurants as the overall population (about 40 minutes).

[Table 2]

The remaining columns of Table 2 (columns 3-4) display the results for families with children.[16] Household heads with children spend less time in bars and restaurants, about 19 minutes. In particular, only 4 minutes per day is spent in that location when accompanied by children (column 4).

[16] Given the small number of smokers (information only available in two of the surveys), we did not attempt to compute statistics for smokers with children.

From the model in Section I.A, a ban on smoking in these locations may affect children in two ways. In a direct way, bans may protect them against exposure to tobacco smoke, and, in an indirect way, those who do not attend those locations may be affected by a change in adult behavior. Adults may in fact spend less time in bars and restaurant once bans are introduced and transfer their smoking activity to locations where children are present.

B. Results using time use data

Table 3 presents the results of the effect of smoking bans in bars and restaurants on time spent in these locations.

[Table 3]

The first panel includes all individuals in the sample. The regression controls for age, sex, race, education, state GDP as well as a state of residence fixed effect and a set of aggregate time indicators. Given the size of the sample and the fact that we only have data for seven years, we do not control for state specific trends which could be correlated with both time spent in various location and anti-smoking policies.

We find that smoking bans in bars and restaurants lead to a decrease of time spent in those locations by about six minutes per day. This effect is robust across days of the week as the size of the coefficient is similar in columns 1, 2 and 3. The introduction of a smoking ban decreases time spent at home and increases time spent in other locations, but we cannot reject a zero effect.

The second panel in Table 3 conditions on smoking status. When we only consider smokers, we find that the significant and negative effect of bans in bars and restaurants on the time spent in these locations is of larger magnitude than when we considered smokers and non smokers together. In particular, we find that a total ban decreases the time spent by smokers in bars and restaurants by about 20 minutes per day. Moreover, as implied by the model presented in section I, we observe an increase of the amount of time that smokers spend at home when a smoking ban in bars in introduced (on average a smokers spend 57 minutes more at home).

The reduction in the amount of time spent by smokers in bars and restaurant due to the introduction of bans is similar during week days and at week-ends (columns 3 and 4). On the other hand the observed increase in the amount of time that smokers spend at home is attributable to weekdays and not to weekends. At weekends displacement occurs from bars towards other locations.

In summary, we find evidence that bans on smoking in bars and restaurants tend to displace customers to different locations. This is particularly true for smokers. We now show evidence using data on cotinine concentration in body fluids.

IV. Effect of Taxes and Bans on Non-Smokers

A. Cotinine as a Proxy for Smoking Intake

In Section II, we investigated the effect of anti-smoking policies on smokers, using cigarette consumption and smoking cessation. In order to analyze the effect of state interventions on *non-smokers* we need a measure of the amount of tobacco smoke inhaled by non smokers. We use the cotinine concentration in body fluids as a proxy. Cotinine is a metabolite of nicotine. While nicotine is unstable and is degraded within a few hours of absorption, cotinine has a half-life in the body of about 20 hours and is, therefore, a biological marker often used as an indicator of passive smoking.[17] It can be measured in, saliva or serum, among other things.

The use of cotinine has several advantages. First, cotinine is related to the exposure to cigarette smoke. Figure 3 plots the relationship between the total numbers of cigarettes smoked in the household and the cotinine level observed in the body fluids of non smokers sharing the house with smokers.

[Figure 3]

The relationship between the number of cigarettes smoked in the household and the cotinine level in non smokers living with smokers is upward sloping. Second, cotinine – and nicotine from which it is derived- is a good proxy for the intake of health threatening substances in cigarettes. The nicotine yield of a cigarette is highly correlated with the level of tar and carbon monoxide, which causes cancer and asphyxiation.[18,19] Cotinine is, therefore, a good indicator of health hazards due to exposure to passive smoking. Third, cotinine levels quickly reveal variation in exposure due to changes in policy, which is not the case with other markers such as tobacco related diseases which take time to develop. Finally, there is minimal measurement error, compared with self-declared exposure to cigarettes, which has been used as a measure of passive smoking. Cotinine is therefore a straightforward and precise measure of passive smoking, particularly suited to evaluate policies aimed at reducing smoking. The drawback of such bio-markers is that it is costly

[17] The elimination of cotinine is slow enough to allow comparing measurements done in the morning or in the afternoon.

[18] Based on our data set (the National Health and Nutrition Examination Survey), which report for some years the nicotine, tar and carbon monoxide yield of each cigarette, the correlations between nicotine and both tar and carbon monoxide are high, 0.96 and 0.85.

[19] The main health impacts of exposure to environmental tobacco smoke (ETS) are lung cancer (more than 50 epidemiological studies have examined the relationship between passive smoking and lung cancer; for a review see NHS Scotland, 2005), coronary heart diseases, respiratory disorders, and ETS in pregnancy can lead to low birth weight and poor gestational growth.

to collect and analyze, and it is rare to obtain large data sets covering many periods and large geographic areas.

We use data from the National Health and Nutrition Examination Survey (NHANES III and NHANES 1999-2006). NHANES is a nationwide representative sample of the US civilian population. In particular, the data set includes a measure of the cotinine concentration in both smokers and non smokers (aged four and above). The number of cigarettes smoked in the household is also reported. The latter allows a distinction between non smokers that are exposed to passive smoke at home and non smokers that live in smoke-free households. For more information on this dataset, we refer the reader to Appendix A3.

From the available sample we select non-smoking individuals. We drop all individuals who report themselves as a smoker or report consumption of cigarettes, cigars, pipes, snuff or chewing tobacco or use nicotine patches. We also drop all individuals who have a cotinine level in excess of 10 ng/ml. This rule is often used in epidemiological studies to distinguish smokers from non smokers.[20] It represents about 5 percent of the declared non smokers. In total, we observe 42,009 non-smokers with a valid measure of cotinine concentration.[21]

B. Trends in Passive Smoking

Before examining regression results, we first provide a discussion on the trends in exposure to tobacco smoke. The cotinine concentration in non-smokers has halved over the 1990s, from about 0.8 ng/ml in 1988 to 0.2 ng/ml in 2006 (Figure 4). This remarkable trend may indicate that policies which regulate smoking have been successful.

[20] See Jarvis et al, 1987. This threshold also constitutes the upper level of exposure of younger children (aged 6 or less) for whom we can presumably assume that they are genuinely non smokers. The distribution of cotinine is very skewed and mainly concentrated in the 0 - 2 ng/ml region which contains more than 90% of the sample.

[21] All valid cotinine measures below the detection threshold (0.035 ng/ml), were set to the threshold value.

[Figure 4]

Next, we separate non smokers who share their household with smokers, from non smokers who live in "smoke free" households. Figure 5 plots the cotinine concentration in non-smokers living in non smoking households from 1988 to 2006. Figure 6 shows, for the same time period, the cotinine concentration of non smokers sharing the house with smokers.

[Figure 5 and Figure 6]

The level of cotinine has been halved in non smokers living with non smokers over the period of analysis (1988-2006), from about 0.36 ng/ml to 0.15 ng/ml. However, policies have been less successful in reducing exposure of those who live with smokers. In the period considered the concentration of cotinine in non-smokers living with smokers does not show a similar trend (Figure 6). Despite the increasing level of severity in regulations and higher excise taxes, this evidence suggests that tobacco exposure of non smokers living in smoking households did not decrease. [22]

C. Effect of Anti-Smoking Policies on Passive Smoking

We now turn to regression results. As detailed in Appendix A3, one limitation of the data set is that not all states are surveyed in each year. This limits the identification of our model in the sense that the data does not support state specific trends. We therefore use region specific trends, using four regions. In addition, we include time-varying state variables that could be correlated both with exposure to tobacco smoke and anti-smoking policies.

[22] An alternative interpretation is that of a change in composition in the pool of smokers. If higher taxes and tougher regulation encourage proportionally more light smokers to quit, the sample of non smokers in smoking household will shift towards a population more exposed to passive smoking. This would bias upward the effect of taxes or regulations. As a robustness check, we have also done the analysis by re-weighting the sample so that each year becomes comparable, in terms of observables, to the first year of our sample. This methodology is developed in DiNardo et al (1996) to study changes in wage inequality and relies on a change in composition which can be corrected by matching on observables. In this way, we are comparing groups of individuals who are similar in a number of observable characteristics. We re-weighted the sample by matching on a number of observable characteristics (sex, race, age group and income group). We found that the results are comparable to the analysis presented above. We provide further evidence in Section IV.E.

These variables are lagged state GDP, lagged smoking prevalence and the lagged proportion of former smokers.

[Table 4]

We first analyse the impact of bans and taxes on passive smoking in the whole sample of non smokers (Table 4, column 1). We then distinguish between four different age groups (columns 2 to 5).

Considering first all non smokers (column 1), we find evidence of an effect of excise taxes on cotinine concentration. In particular doubling excise taxes reduces cotinine in non-smokers by 0.06 ng/ml. We observe an increase in the level of cotinine in non smokers due to the introduction of smoke free bans both in the workplace and in bars and restaurants, though both coefficients are not significantly different from zero. In fact, the model derived earlier shows that the overall effect of smoking bans is ambiguous and depends on the relative amount of time spent by individuals in different locations.
From a policy perspective, these results are interesting, although disheartening, as they suggest that, overall, bans do not protect non-smokers from exposure to tobacco smoke. However, such policies may have redistributive effects across age groups that we now report.

The remaining columns of Table 4 separate non-smokers by age groups. In particular we distinguish between four different age groups. The first age group is from 4 to 8, an age where children are mostly either at home or in school or day-care, and supervised by an adult. At that age, it is unlikely that any peers would be smoking. These individuals are therefore exposed either to ETS at home, where parents or other adults in the household smoke, or in public places. The second age group ranges from 9 to 12, an intermediate age group between early childhood and adolescence. The third age group ranges from 13 to 19. Exposure for these individuals would come from parents and also from peers.

Finally, we group all individuals aged 20 or above into group 4. We have experimented with different cut-off ages, in particular with younger and older adults, and have found similar results.

Tighter regulations have different effects on the cotinine concentration depending on where they are enforced. When we consider different age groups separately, we observe that tighter bans in the workplace lead to an increase of cotinine levels particularly in children. Increasing the coverage of smoking bans in the workplace by 100 percent increases the exposure of children aged 4-8 by about 0.66 ng/ml. However this coefficient is not statistically significant. Stricter bans also lead to an increase in cotinine in children aged 8 to 12. For them the effect is smaller (0.37 ng/ml) but strongly significant. The effect of tighter regulations in the workplace is not statistically different from zero both for teenagers and adults.

The effect of tighter smoking regulations in bars and restaurants is not significantly different from zero. This is the case for all age groups apart from teenagers. For individuals aged 13-19 we observe a displacement effect of bans in these locations. An increase of ban coverage in bars by 100 percent increases teenagers' exposure by about 0.55 ng/ml.

While bans lead to an unwanted increase in cotinine level in non smokers, higher taxes have the desired effect of reducing cotinine levels. In particular this is true for children. For children aged 4 to 8, a doubling of taxes decreases the cotinine concentration by 0.21 ng/ml. For children aged 8-12 the effect is of similar size (the doubling of taxes leads to a decrease of 0.23 ng/ml in the cotinine level). Expressed in terms of elasticities, these results imply an elasticity of exposure to tobacco smoke with respect to excise taxes of -0.36, which is almost three times as large as the tax elasticity of cigarette sales. This is evidence that cigarettes smoked in the presence children are the first to be cut as a result of a change in taxes. This suggests that smoking is partly a social activity so that smokers derive more utility when smoking with other adults. An alternative explanation could be that adults with children are poorer and face liquidity constraints, which would make them more sensitive to a change in tobacco prices. The empirical literature has in fact documented the higher price elasticity for poorer individuals (Chaloupka (1991), Farrelly et al (1998)). We take this into account by conditioning our results on family income and occupation of the head of household.[23]

D. Uncovering Displacement Effects

To probe further the results discussed up to here, we contrast the effect of these policies on groups of individuals who are more or less likely to be affected by the policy. For example, one would expect larger effects for non-smokers living with smoking adults than for those in smoke-free households. Moreover, any effect of smoking bans in workplaces should be larger during week days than at week-ends.

We therefore estimate the following model:

$$\begin{aligned}(10)\qquad \mathrm{Cot}_{ist} &= \beta_W B_{st}^{W} + \beta_{go} B_{st}^{go} + \beta_T \log Tax_{st} + X_i\gamma + \lambda(s,t) \\ &+ \beta_D D_i + \beta_{DW} D_i B_{st}^{W} + \beta_{Dgo} D_i B_{st}^{go} + \beta_{DTax} D_i \log Tax_{st} + \varepsilon_{ist}\end{aligned}$$

where Cot_{ist} is the cotinine concentration (expressed in ng/ml) and the remaining variables are defined in a similar way as in section I.B. D_i is an indicator for being tested for cotinine during weekends. We estimate this model by age group and by family smoking status.

[23] We check the robustness of these results in Table A 3 in the Appendix by regressing cotinine levels on leads of anti-smoking policies. We cannot reject that the "effects" of the policies are equal to zero, which may indicate that regional trends provides a rich enough structure to get rid of potential confounding trends.

Table 5 reports the effect of changes in taxes and smoking bans by household smoking status, age group and day of the week. [24]

[Table 5]

Changes in regulations and in taxes do not appear to have an effect on individuals living in non-smoking households when we consider all age groups together. The model presented in section I predicts this to be the case if non-smokers spend little time in public places where bans are enforced. In addition, it could be the case that prior to the 100% smoke free laws, non-smokers were protected in public places by other means. For instance, it is possible that ventilation was already in place and was relatively efficient before stricter bans were in place, or that non-smokers were able to avoid exposure in designated areas.We do find, however, evidence of displacement for children following the introduction of bans in bars and restaurants. The observed increase in cotinine in children could be due to displacement of smokers who come to visit following the introduction of a ban in public places.

The effect on non-smokers living in households with smokers is of particular interest. There is a marked increase in cotinine levels following a tightening of workplace bans on weekdays. A 100 percent increase in ban coverage increases cotinine levels by 0.9 ng/ml. This effect, in line with the empirical implications of the model, is particularly large for children, an age group that do not spend any time in the workplace.

The effect of smoking bans in bars and restaurants also depends on the day of the week. In particular, we cannot detect an effect during weekdays, but we find a significant increase of cotinine levels in non-smokers during week-ends. A 100 percent increase in coverage increases children's cotinine levels by 0.8 ng/ml. These results are consistent with what is observed using time use data in Section III.B. Smokers spend less time in

[24] In this analysis, we grouped all children together (aged 4 to 18) as we also divide the sample by household smoking status and day of the week, which leads to smaller cells than in the previous analysis.

bars and restaurants following the introduction of smoking bans in those locations, which would tend to increase the exposure of other family members in private places. In addition, smoking bans decrease the amount of time spent with children during week-days, which could explain the negative effect of bans in bars and restaurants during week-days for children in smoking households.

We find displacement effects for bans in both workplace and bars and restaurants, which leads to an increase in cotinine levels in children approximately equal to 1ng/ml. We now investigate whether the size of this effect is plausible given the increase in the amount of time spent at home and the quantity of cigarettes smoked. Looking at data on cotinine and number of cigarettes smoked as displayed in Figure 3, we find that each cigarette smoked increases the cotinine concentration of children by 0.1ng/ml. However, we have to take into account that not all cigarettes are smoked in the presence of children. In particular, from Table 2, data on time use indicate that the time that adults spend with children is roughly a third of a day. Hence, each cigarette smoked in the presence of children adds about 0.3ng/ml to cotinine levels. The displacement effect we observe corresponds therefore to a plausible increase of about two to four cigarettes per day smoked in the presence of children.

The effect of taxes on non-smokers' exposure is expected to be unambiguous. In particular, from the model presented earlier, we expect to find an effect of taxes for non-smokers living with smokers. We find a significant effect of taxes for children living in smoking families, where a 100 percent increase in the excise tax reduces cotinine levels by 0.3 to 0.5ng/ml, depending on the day of the week.

Overall, the observed displacement effects are consistent with the predictions of the model presented in section I. The effect is particularly strong for individuals who do not spend much time in public locations (i.e. children) and therefore are mainly indirectly affected by the policy.

E. Controlling for the Potential Endogeneity of Bans and Taxes: Triple Difference Estimates

The approach we are taking allows us to go one step further regarding the potential endogeneity of smoking bans, although we already control for a number of observed characteristics. Denote anti-smoking policies such as bans and taxes by P_i and let D_i be an indicator for being tested for cotinine during week-ends.

Assume that $E(P_i \mid D_i) = E(P_i)$, $E(P_i u_i \mid D_i) = E(P_i u_i)$ and $E(u_i D_i) = 0$. The first expression states that bans and taxes are independent of the day of the week. The second expression implies that the potential endogeneity of regulations is orthogonal to the day when individuals are tested. Note that we do not require smoking bans or taxes to be exogenous. Finally, the last assumption requires that individuals are randomly sampled throughout the week.

Under these assumptions, the estimators of β_{DW} , β_{Dgo} and β_{DTax} in model (10) are consistent, even if bans or taxes are endogenous. The intuition behind this result is that these coefficients capture the differential impact of the policies across days of the week.[25] This procedure is known as a triple difference estimator.

Coming back to Table 5, this econometric result implies that the difference in the effect of smoking bans across days of the week is consistently estimated. These effects are displayed in the last three columns of Table 5. For instance, bans in the workplace increase the cotinine exposure of individuals living with smokers during week-days by 0.79ng/ml. Similarly, the effect of bans in bars for this group of individuals is an increase of 0.63ng/ml in cotinine levels during week-ends. This is evidence of displacement effects from public places to private ones, as outlined in the model in Section I.A, and holds even when we relax the assumption of the exogeneity of bans and taxes.

[25] We refer the reader to Appendix B for a proof.

The results in Table 5 separate smoking households from non-smoking ones. As we show in Figure 2, the prevalence of smoking has decreased over the last two decades. One may worry that part of the results discussed above are due to the change in composition of the sample. This is true in particular for households with smokers, as they form a smaller group. Anti-smoking policies may selectively induce some type of smokers to quit. For instance, if light smokers or smokers who care about their non-smoking relatives are more prone to quit, we may expect to see a spurious increase in cotinine levels. It is not easy to control for such a phenomenon, especially when only cross-sectional data is available. However, first, we note that we do not find much support in Section II for the fact that smoking bans induce smokers to quit. This does not necessarily imply that there is no selection in quitting, but its magnitude is likely to be small, as we do not find an overall effect of bans on quitting. Second, to probe further the robustness of the results, we follow DiNardo et al (1996) and reweight our regressions with weights constructed such that we keep the characteristics of the sample constant across time. We implement this by state and match on observed characteristics such as age, age of the reference person, race, education level of the reference person and income levels. We use a propensity score approach, where we first regress an indicator of smoking within the household on household characteristics. We then construct the weights using this score.

We provide the results in Table A 4 in the Appendix. The results are robust. The most noticeable change is the effect of workplace bans on children during weekdays. The effect decreases from 1.2ng/ml to 0.6ng/ml. However, given the size of the standard errors, we cannot reject the hypotheses that these two numbers are equal.

We provide further robustness checks in Table A 5 in the Appendix, where we lead the policy variables. The results are somewhat mixed, as several coefficients appear significant. This may be due to the size of the sample, and the fact that region specific time trends may not be enough to capture confounding trends. However, generally, the magnitudes of the effects are smaller, especially for the effect of excise taxes and smoking bans in bars and restaurants.

V. Conclusion

The effect of passive smoking is of increasing public concern. Although the economic literature has evaluated the effect of government intervention on smoking intensity or prevalence, there has been, so far, no direct evaluation of these measures on non-smokers.

In this paper, we characterize the extent of exposure to environmental smoke, and evaluate the effect of changes in excise taxes and bans on passive smoking. We use a direct measure of passive smoking, which has not been used in the economic literature, the concentration of cotinine, a metabolite of nicotine, which is present in body fluids of both smokers and non-smokers. This allows us to precisely identify the effect of state intervention on non-smokers.

We find that increasing taxes on cigarettes reduces average exposure to cigarette smoke of non-smokers. The effect of state excise taxes also varies across demographic groups. We find that taxes have a strong effect on young children living with smokers but no effect on non-smoking adults. This suggests that smokers cut down on the cigarettes they smoke at home but not those in social activities with other adults.

Using information on the implementation of smoking bans across time and different US states, we find that smoking regulations can have perverse effects on non-smokers. By displacing smoking, and to some extent smokers, bans can contribute to an increase in exposure to tobacco smoke. This effect is particular strong for young children, and those living with smokers.

Our results question the usefulness of bans in reducing smoking exposure for non-smokers. More precisely, we show that policies aimed at reducing exposure to tobacco smoke induce changes in behavior, which can offset these policies. It is therefore of crucial importance to understand how smoking behavior is affected by regulations. So far, the literature has not gone far enough in studying smoking behavior to be able to evaluate their effect on non-smokers. It is not enough to show that smokers react to prices or taxes. Information on which particular cigarette is cut down during the day, where smokers smoke and with whom are also relevant. There are complex interactions at play and considerable heterogeneity in their effects across socio-demographic groups. Using a biomarker such as cotinine concentrations is a very direct way of evaluating the overall effect of interventions and the induced changes in behavior.

On the policy side, it seems therefore important when designing public policies aimed at reducing tobacco exposure of non-smokers to distinguish between the different public places where bans are introduced. Displacing smoking towards places where non-smokers spend time is particularly inefficient. It may also increase health disparities across socio-economic groups and in particular in children. There are several reasons why one may want to protect children. They constitute a vulnerable group with little choice to avoid contamination. This age group is particular prone to tobacco related diseases and poor health in childhood has lasting consequences not only for future health but also for the accumulation of human capital (Case et al, 2005).

Governments in many countries are under pressure to limit passive smoking. Some pressure groups can be very vocal about these issues and suggest bold and radical reforms. Their point of view is laudable, but too simplistic in the sense that they do not take into account how public policies can generate perverse incentives and effects. This paper provides insights on how to design optimal policies to curb passive smoking.

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Appendix A: Data Description

A.1. Data on Smoking Behavior

We use data from the Behavioral Risk Factor Surveyance System (BRFSS) to get information on prevalence and smoking cessation. Data on cigarette sales are obtained from the State Tobacco Activities Tracking and Evaluation System at the Center for Disease Control.

The BRFSS is a survey, which collects data on health risk behavior since 1984 and is run by the Center for Disease Control. Data is collected monthly by a phone interview. In 1984, 15 states were covered, and this number increased to 40 in 1989 and then 50 in 1993. As a consequence, the size of the survey has grown from 12,258 in 1984 to over 355,000 in 2006.
Individuals eighteen and older are surveyed and weights are provided to make the sample representative of the US non-institutionalized adult population. Only one individual per household is part of the survey. The data set reports demographics as well as individual smoking behavior. In total we have valid information about demographics and behavior on 3,221,870 individuals.

We use three indicators of smoking behavior, smoking prevalence (current smokers), the proportion of former smokers (defined as having smoked at least 100 cigarettes in own's lifetime) and attempted quits (within the last year).

Data on cigarette sales are expressed as the number of cigarettes per adult capita and per day. The data ranges from 1970 to 2007.[26] In total, we have 1,938 state-year observations.

A.2. Time Use Data

We use two different surveys, the National Human Activity Pattern Survey (NHAPS) which covers the years 1992 to 1994 and the American Time Use Survey (ATUS), which covers the year 2003 to 2006.

The NHAPS is a representative US human activity pattern survey which was conducted for the US Environmental Protection Agency. It consists of a 24 hour diary collected from 9386 individuals between 1992 and 1994, in all main-land US states. Each activity is recorded with an indication of the location, its duration and the presence of other persons (children in particular).
The locations are coded into nine categories (Own house, Other people's house, Workplace, School, Services and shops, Restaurants and Bars, Church, Traveling, Other).

[26] The data can be obtained from the Center and Disease Control (http://apps.nccd.cdc.gov/StateSystem).

The dataset provides information on basic demographics (age, sex, race and education) as well as smoking status.

The ATUS provides nationally representative estimates of how adults spend their time, with an indication of location for each activity as well as the presence of children. We linked the ATUS file to the 2003 Tobacco Supplement of the Current Population Survey (CPS) to get information on smoking status. There is no information available on smoking status in other years. In total, we have information on 60,674 individuals across all US states.
The locations were also grouped into the same categories as NHAPS. The same set of individual characteristics is available.

For the purpose of the analysis, we pooled both data sets together, which provide valid information for 67,250 individuals. We computed the total time each individual spends in a specific location during the last 24 hours of the survey, expressed in minutes per day. We also compute the time spent with children in different locations. In all statistical computations, we use the weights provided in each data set to make it representative.

A.3. NHANES

The National Health and Nutrition Examination Survey (NHANES) is designed to assess the health and nutrition status of adults and children in the United States. For the purpose of this study, we pooled together the NHANES III, covering the periods 1988 to 1994 and the latest NHANES waves from 1999 to 2006.

The data set reports information on the age, sex, race, health, education and occupation of the individual, as well as information at the household level such as family composition, income or geographical location. In addition, the data set also reports cotinine concentration in body fluids for individuals aged four and above.

Approximately 5,000 persons are surveyed each year, across the US. The dataset contains a total of 70,303 individuals, out of which 57,950 are classified as non smokers. 42,009 individuals have a valid cotinine measure. Two third of those without a cotinine measure are children below the age of 5, for whom no samples were taken. Most missings are from children below the age of 18. We use weights to take into account this pattern.

We define an individual as a non smoker if that person reports not to be currently smoking or consuming tobacco through other ways (snuff, pipe). In addition, we classify as smokers all those who have a cotinine concentration above 10ng/ml, a standard cut-off point in the medical and epidemiology literature.

One limitation of the dataset is that not all states are surveyed every year. Although, we potentially have data over fifteen years and for 51 states, in practice, the time span is shorter. Out of 765 potential state-year cells, the data has only information on 156 of them.[27] For 12 states, we have less than two points of observations, which is the minimum time span to include a state fixed effect. The states which have been surveyed most have information for 14 years.

Table A 2 provides a summary statistic of the data set. Column 1 refers to the whole sample, columns 2 and 3 provide descriptive statistics for non-smokers living in household where the other members either smoke or not. The average cotinine concentration is equal to 0.36ng/ml.
69 percent of the sample has a cotinine concentration higher than the detectable threshold of 0.035ng/ml, while nine percent have a value higher than 1ng/ml. The amount of cotinine in non smokers living in a non smoking household is almost seven times lower than the amount of cotinine present in individuals living with smokers (0.21 n/ml in non-smokers living in non-smoking households compared to a level of 1.43 n/ml in individuals living with smokers). Individuals living in households with smokers have almost all detectable levels of cotinine, and are much more likely than non smokers living in non smoking households to have a concentration of cotinine above 1ng/ml.
The average individual in a household where a smoker is present is younger than the average as smokers tend to quit as they age and young adults are more likely to have children living with them. Individuals in households with smokers are also more likely to be African-American.

Appendix B: Proof

Suppose the following model holds for individual *i*:

$$y_i = \alpha_0 + \alpha_P P_i + \alpha_D D_i + \alpha_{PD} P_i D_i + u_i \qquad i = 1, \dots N$$

where D_i is an indicator variable with $E(P_i \mid D_i) = E(P_i)$, $E(P_i u_i \mid D_i) = E(P_i u_i)$ and $E(u_i D_i) = 0$. We place no restriction on the covariance between P_i and u_i , i.e. we allow for the possible endogeneity of P_i . Denote $\hat{\alpha}_{P,N}$, $\hat{\alpha}_{D,N}$ and $\hat{\alpha}_{PD,N}$ the OLS estimators of the parameters α_P , α_D and α_{PD} .

Proposition:

Under the assumptions detailed above, when N tends to infinity,

[27] Confidentiality requirements prevent us from listing which states have been surveyed and the date of the survey.

$$\underset{N\to\infty}{p\lim}(\breve{\alpha}_{P,N} - \alpha_P) \neq 0$$
$$\underset{N\to\infty}{p\lim}(\breve{\alpha}_{D,N} - \alpha_D) = 0$$
$$\underset{N\to\infty}{p\lim}(\breve{\alpha}_{PD,N} - \alpha_{PD}) = 0$$

Assume that $E(P_i \mid D_i) = E(x_i) = \overline{P}$, where upper bar variables denote variable means. Let $Z = [1, P_i, D_i, P_i D_i]$ be N by 4 matrix and let σ_P^2 denote the variance of P_i , σ_{Pu} and σ_{Du} the covariance between P_i and u_i and D_i and u_i . The expression for the asymptotic bias can be expressed (after some straightforward algebra):

$$E\left(\frac{Z'Z}{N}\right)^{-1}\frac{Z'u}{N} = \begin{bmatrix} \dfrac{-\overline{P}\sigma_{Pu}}{\sigma_P^2} \\ \dfrac{\sigma_{Pu}}{\sigma_P^2} \\ 0 \\ 0 \end{bmatrix}$$

Table 1: Effect of Bans and Taxes on Smoking in Adults.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Smoking Prevalence	Smoking Prevalence	% Former Smokers	% Former Smokers	Attempted Quits	Attempted Quits	Per Capita Cigarette Sales	Per Capita Cigarette Sales
Smoking Ban Workplace	0.216	0.254	-0.785	0.242	1.656	2.213	-0.225	-0.407
	(0.33)	(0.38)	(0.47)	(0.71)	(2.00)	(1.68)	(0.24)	(0.24)
Smoking Ban Bar & Restaurants	-2.02**	-0.009	1.900**	-0.948**	-2.324	-2.638**	-0.256**	0.370*
	(0.23)	(0.25)	(0.22)	(0.41)	(1.56)	(1.11)	(0.11)	(0.21)
Log Tax	-0.74**	-0.18	0.668**	0.272	1.01**	0.373	-1.026*	-0.560**
	(0.23)	(0.33)	(0.32)	(0.43)	(0.36)	(0.42)	(0.11)	(0.10)
Number of observations	3,215,506	3,215,506	1,544,761	1,544,761	609,686	609,686	1,938	1,938
Mean of dependent variable	22.9	22.9	51.5	51.5	53.6	53.6	5.86	5.86
Trends	Aggregate	State Specific	Aggregate	State Specific	Aggregate	State Specific	Aggregate	State Specific
Years	1984-2006	1984-2006	1984-2006	1984-2006	1990-2006	1990-2006	1970-2007	1970-2007

Notes: Regressions control for age, sex, race, education and state specific GDP. Robust standard errors clustered at state level are shown in parenthesis. Columns (1) to (6) use data from the BRFSS. Columns (7) and (8) use per capita sales of cigarettes data from the State Tobacco Activities Tracking and Evaluation System. **,* significant at 5%, 10%.

Table 2: Descriptive Statistics: Time Spent in Different Locations (Minutes per Day)

	(1)	(2)	(3)	(4)
	All	Smokers	Household with Children	
	Total Time	Total Time	Total Time	Time with Children
Home	1027.5	1018.6	1004.8	398.2
	(286.8)	(288.0)	(279.4)	(471.9)
Restaurants & Bars	24.8	40.5	19.7	4.5
	(67.2)	(105.1)	(58.5)	(19.9)
Other	387.6	380.8	415.4	58.3
	(280.7)	(279.5)	(276.2)	(120.5)
Number of observations	66,880	3,079	30,616	29,063

Notes: All times are in minutes per day. Time Use data, for the years 1992-1994 and 2003-2006. Standard deviations in parenthesis.

Table 3: Effect of Smoking Bans on Time Spent in Different Locations

	All Days	Week Days	Week-End	N
All Population.				
Home	-4.84	-11.45	9.70	66,833
	(12.88)	(11.43)	(9.86)	
Restaurants & Bars	-6.35**	-6.26*	-6.62**	66,833
	(3.10)	(3.60)	(2.90)	
Other	11.19	17.71*	-3.08	66,833
	(10.50)	(9.09)	(8.98)	
Smokers				
Home	56.95*	98.31**	-41.35*	3,065
	(34.13)	(45.21)	(22.77)	
Restaurants & Bars	-21.44**	-22.23**	-18.13**	3,065
	(6.27)	(6.85)	(7.73)	
Other	-35.51	-76.08	59.48**	3,065
	(36.24)	(47.46)	(22.46)	

Notes: Regression controls for age, sex, education, race, state GDP, year indicators and state indicators. Robust standard errors are clustered by state. Data covers 1992-1994 and 2003-2006. **,* significant at 5%, 10%.

Table 4: Effect of Anti-Tobacco Policies on Non Smokers, by Age. Dependent variable: Cotinine.

	(1)	(2)	(3)	(4)	(5)
	All Ages	Age<8	Age 8-12	Age 13-19	Age 20+
Average Cotinine Level	0.36	0.71	0.49	0.56	0.27
(Standard deviation)	(0.93)	(1.38)	(0.99)	(1.22)	(0.75)
Smoking Ban Workplace	0.1476	0.661	0.3752**	-0.1995	0.0766
	(0.127)	(0.376)	(0.111)	(0.206)	(0.104)
Smoking Ban Bar & Restaurants	0.0355	0.0005	-0.0305	0.5506**	-0.0118
	(0.074)	(0.182)	(0.097)	(0.191)	(0.065)
Log Tax	-0.0585*	-0.2111**	-0.2304**	0.0079	-0.0369
	(0.031)	(0.117)	(0.045)	(0.069)	(0.023)
Sample Size	37,084	5,154	4,245	7,571	20,114

Notes: Regression controls for age, sex, race, income, age of household reference person, education of the head of household, state fixed effects, state GDP, lagged state prevalence, lagged state quitting rate and region specific time effects. Robust standard errors clustered at state level are shown in parenthesis. **,* significant at 5%, 10%.

Table 5: Effect of Anti-Tobacco Policies on Non Smokers, by Family Smoking Status, Day of Week and Age. Dependent variable: Cotinine.

	Non-Smoking Families								
	Week Days			Week-ends			Difference		
	All	Children	Adults	All	Children	Adults	All	Children	Adults
Smoking Ban Workplace	-0.001	-0.084	0.020	-0.012	-0.219	0.039	0.011	0.135	-0.019
	(0.115)	(0.135)	(0.113)	(0.065)	(0.113)	(0.063)	(0.0635)	(0.084)	(0.065)
Smoking Ban Bar & Restaurants	0.015	0.198**	-0.029	0.038	0.217**	0.000	-0.023	-0.019	-0.029
	(0.065)	(0.077)	(0.067)	(0.045)	(0.058)	(0.048)	(0.033)	(0.037)	(0.035)
Log Tax	-0.005	0.019	-0.015	-0.002	0.015	-0.012	-0.003	0.004	-0.004
	(0.022)	(0.036)	(0.027)	(0.019)	(0.035)	(0.019)	(0.014)	(0.028)	(0.017)
Sample Size	30,736	11,700	19,036	30,736	11,700	19,036	30,736	11,700	19,036
	Smoking Families								
	Week Days			Week-ends			Difference		
	All	Children	Adults	All	Children	Adults	All	Children	Adults
Smoking Ban Workplace	0.953**	1.160**	-0.224	0.161	-0.283	0.532	0.792**	1.443**	-0.756*
	(0.431)	(0.413)	(0.335)	(0.184)	(0.469)	(0.377)	(0.392)	(0.589)	(0.388)
Smoking Ban Bar & Restaurants	-0.264	-0.635	0.499	0.365	0.832**	-0.044	-0.630**	-1.467**	0.543**
	(0.359)	(0.330)	(0.300)	(0.194)	(0.382)	(0.395)	(0.310)	(0.523)	(0.235)
Log Tax	-0.069	-0.301**	0.150	-0.144	-0.501**	0.200	0.075	0.200**	-0.051
	(0.105)	(0.137)	(0.179)	(0.111)	(0.108)	(0.236)	(0.081)	(0.078)	(0.111)
Sample Size	6,340	4,127	2,213	6,340	4,127	2,213	6,340	4,127	2,213

Notes: Regression controls for age of individual, age of household reference person, sex, race, household income, education of household reference person, state indicators, lagged state prevalence, lagged state quitting rate and region specific time effects. Children are of age 4 to 18. Robust standard errors clustered at state level are shown in parenthesis. **,* significant at 5%, 10%.

Table A 1: Placebo: Policy Variables Leaded. Smoking Behavior

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Smoking Prevalence	Smoking Prevalence	% Former Smokers	% Former Smokers	Attempted Quits	Attempted Quits	Per Capita Cigarette Sales	Per Capita Cigarette Sales
Smoking Ban Workplace	0.36	-0.12	-1.12**	-0.21	1.52	-1.56	-0.137	-0.310
	(0.33)	(0.59)	(0.28)	(0.81)	(1.45)	(1.24)	(0.25)	(0.20)
Smoking Ban Bar & Restaurants	-1.77**	-0.14	2.23**	0.72	-0.67	1.50*	-0.692**	0.026
	(0.27)	(0.44)	(0.31)	(0.47)	(1.30)	(0.78)	(0.19)	(0.16)
Log Tax	-0.15	-0.21	0.31	0.46	0.82	0.14	-0.683**	-0.083
	(0.19)	(0.16)	(0.22)	(0.34)	(0.59)	(0.51)	(0.11)	(0.06)
Number of observations	3,221,870	3,221,870	1,547,452	1,547,452	610,523	610,523	1,785	1,785
Mean of dependent variable	22.9	22.9	51.5	51.5	53.6	53.6	5.86	5.86
Trends	Aggregate	State Specific	Aggregate	State Specific	Aggregate	State Specific	Aggregate	State Specific
Years	1984-2006	1984-2006	1984-2006	1984-2006	1990-2006	1990-2006	1970-2007	1970-2007

Notes: Regressions control for age, sex, race, education and state specific GDP. Robust standard errors clustered at state level are shown in parenthesis. All policy variables are leaded three years. Columns (1) to (6) use data from the BRFSS. Columns (7) and (8) use per capita sales of cigarettes data from the State Tobacco Activities Tracking and Evaluation System.

Table A 2: NHANES, Descriptive Statistics

	Whole sample	Individuals in smoking families	Individuals in Non smoking families
Number of observations	42,009	7,231	34,529
Average level of cotinine (ng/ml)	0.36	1.43	0.21
	(0.92)	(1.56)	(0.68)
Proportion with detectable cotinine measure (>0.035 ng/ml)	69%	99%	64%
Proportion with cotinine >1 ng/ml	9%	46%	4%
Proportion with cotinine >5 ng/ml	1%	4%	0.5%
Average age	34.2	22.7	35.9
Age range	0-90	0-90	0-90
Male	46%	46%	46%
White	70%	70%	70%
Black	12%	18%	11%

Note: Standard deviations in parenthesis. The whole sample consists of all non-smoking individuals who have a valid cotinine measure lower than 10ng/ml.

Table A 3: Placebo: Policy Variables Leaded. Evidence from NHANES.

	(1)	(2)	(3)	(4)	(5)
	All Ages	Age<8	Age 8-12	Age 13-19	Age 20+
Average Cotinine Level	0.36	0.71	0.49	0.56	0.27
(Standard deviation)	(0.93)	(1.38)	(0.99)	(1.22)	(0.75)
Smoking Ban Workplace	-0.0125	-0.0502	-0.0752	0.1793	-0.1107
	(0.059)	(0.171)	(0.109)	(0.104)	(0.068)
Smoking Ban Bar & Restaurants	-0.0562	-0.2365	0.3615	0.2702	-0.0669
	(0.043)	(0.211)	(0.221)	(0.196)	(0.115)
Log Tax	0.0419	0.099	-0.0169	0.1467	-0.0018
	(0.051)	(0.241)	(0.089)	(0.090)	(0.044)
Sample Size	31,291	4,404	3,553	6,195	17,139

Notes: Regression controls for age, sex, race, income, age and education of household reference person, state fixed effects, state GDP and year time effects. All policy variables are leaded three years. Standard errors clustered at state level. **,* significant at 5%, 10%.

Table A 4: Effect of Anti-Smoking Policy on Cotinine Levels. Re-Weighted Regressions.

	Non-Smoking Families								
	Week Days			Week-ends			Difference		
	All	Children	Adults	All	Children	Adults	All	Children	Adults
Smoking Ban Workplace	0.001	-0.115	0.041	-0.062	-0.216	0.000	0.063	0.101	0.041
	(0.125)	(0.156)	(0.122)	(0.089)	(0.127)	(0.088)	(0.060)	(0.100)	(0.051)
Smoking Ban Bar & Restaurants	0.029	0.176**	-0.002	0.018	0.211**	-0.030	0.011	-0.035	0.028
	(0.065)	(0.091)	(0.067)	(0.047)	(0.067)	(0.059)	(0.048)	(0.038)	(0.063)
Log Tax	-0.034	0.004	-0.051	0.006	0.004	0.002	-0.041	0.000	-0.053
	(0.022)	(0.030)	(0.029)	(0.022)	(0.031)	(0.024)	(0.031)	(0.033)	(0.033)
Sample Size	30,597	11,615	18,982	30,597	11,615	18,982	30,597	11,615	18,982
	Smoking Families								
	Week Days			Week-ends			Difference		
	All	Children	Adults	All	Children	Adults	All	Children	Adults
Smoking Ban Workplace	1.000**	1.137**	-0.388	0.456	0.672	0.487	0.544	0.465	-0.875**
	(0.367)	(0.383)	(0.612)	(0.361)	(0.504)	(0.621)	(0.289)	(0.431)	(0.260)
Smoking Ban Bar & Restaurants	0.052	-0.285	1.048	0.581	0.452	0.533	-0.530*	-0.737**	0.515
	(0.433)	(0.404)	(0.677)	(0.446)	(0.476)	(0.680)	(0.257)	(0.245)	(0.324)
Log Tax	0.328**	0.039	0.766**	0.170	-0.326**	0.754	0.158	0.365**	0.011
	(0.144)	(0.175)	(0.286)	(0.177)	(0.143)	(0.399)	(0.120)	(0.093)	(0.204)
Sample Size	5,715	3,716	1,999	5,715	3,716	1,999	5,715	3,716	1,999

Notes: Regression controls for age of individual, age of household reference person, sex, race, household income, education of household reference person, state indicators, lagged state prevalence, lagged state quitting rate and region specific time effects. Children are of age 4 to 18. Robust standard errors clustered at state level are shown in parenthesis. **,* significant at 5%, 10%.

Table A 5: Placebo: Policy Variables Leaded: Evidence from NHANES

	Non-Smoking Families						Smoking Families					
	Week Days			Week-ends			Week Days			Week-ends		
	All	Children	Adults	All	Children	Adults	All	Children	Adults	All	Children	Adults
Smoking Ban Workplace	-0.07	-0.03	-0.09	-0.13**	-0.10	-0.15**	0.51**	0.75**	0.13	0.22	-0.40	1.10**
	(0.05)	(0.08)	(0.07)	(0.05)	(0.09)	(0.06)	(0.19)	(0.26)	(0.20)	(0.23)	(0.39)	(0.23)
Smoking Ban Bar & Restaurants	-0.00	0.20**	-0.05	-0.00	0.06	0.00	-0.15	-0.21	-0.33	0.02	0.66	-1.03**
	(0.09)	(0.09)	(0.11)	(0.08)	(0.08)	(0.10)	(0.26)	(0.43)	(0.31)	(0.27)	(0.47)	(0.30)
Log Tax	-0.04	-0.06	-0.03	-0.03	0.02	-0.04	-0.05	0.05	-0.18	0.02	0.05	-0.02
	(0.03)	(0.07)	(0.04)	(0.04)	(0.05)	(0.04)	(0.17)	(0.20)	(0.21)	(0.15)	(0.19)	(0.20)
Sample Size	25,531	9,460	16,071	25,531	9,460	16,071	5,752	3,730	2,022	5,752	3,730	2,022

Notes: Regression controls for age, sex, race, income, age and education of household reference person, state fixed effects, state GDP and year time effects. Children are of age 4 to 18. All policy variables are leaded three years. Standard errors clustered at state level. **,* significant at 5%, 10%.

Figure 1: Bans and Excise Taxes by Year (US Average)

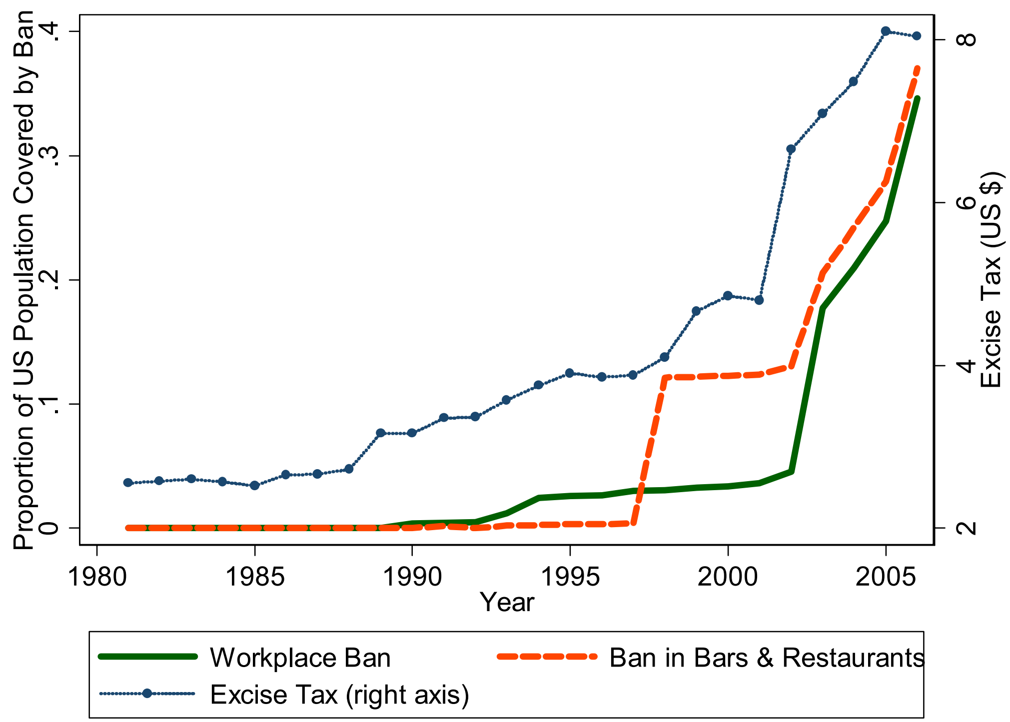

Figure 2: Trends in Smoking Behavior

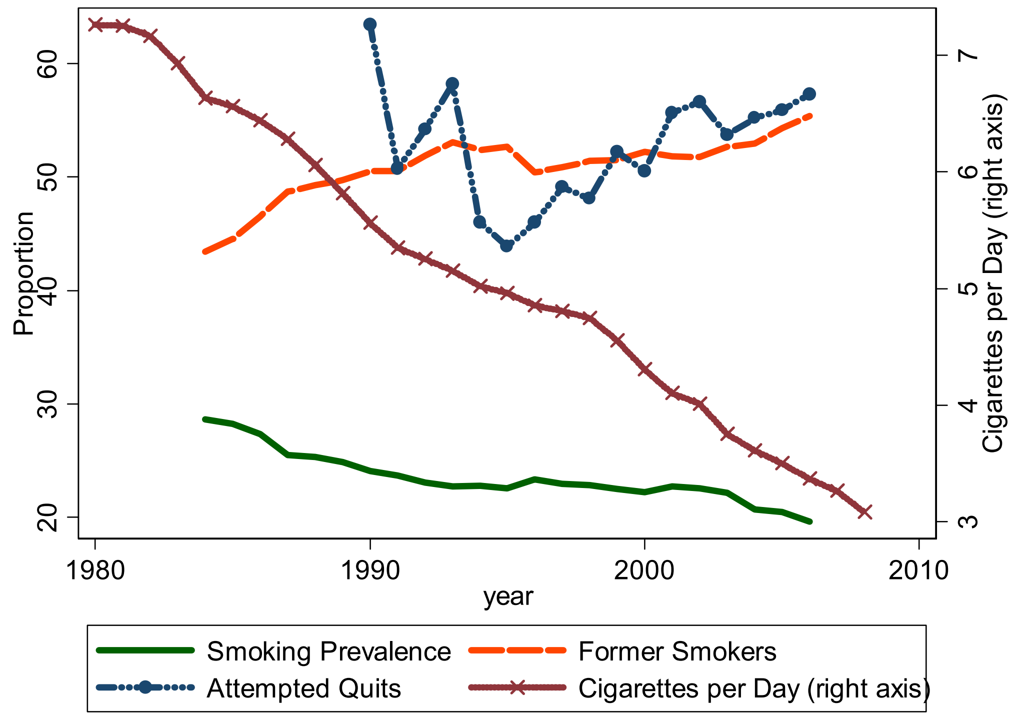

Figure 3: Cotinine Level by Number of Cigarettes Smoked in the Household

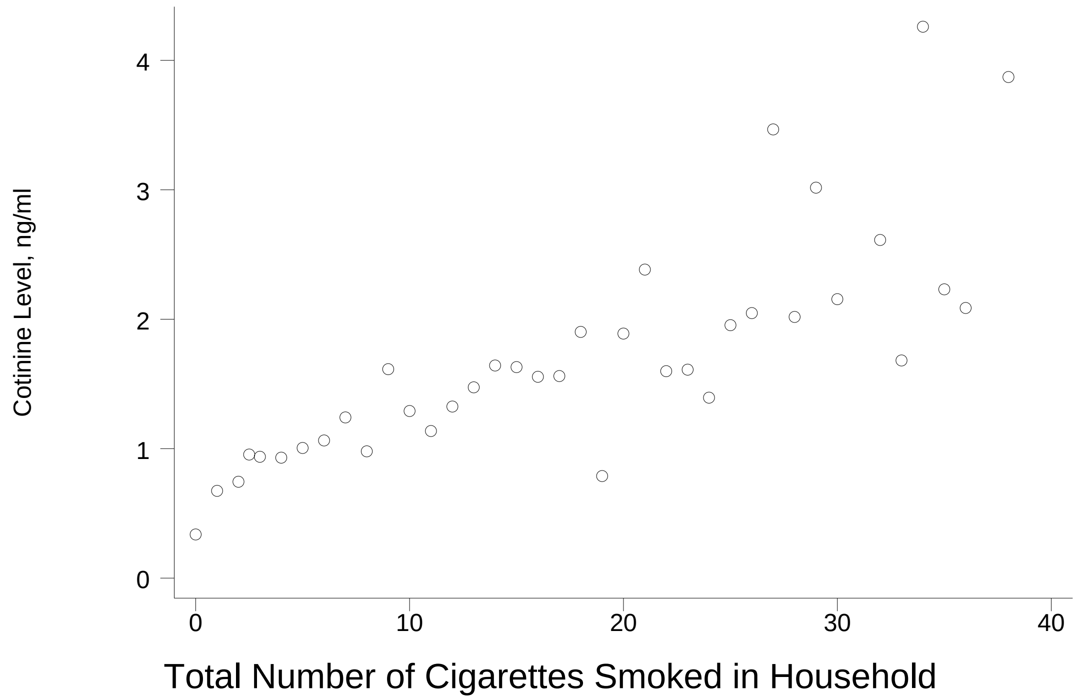

Figure 4: Average Cotinine in Non Smokers

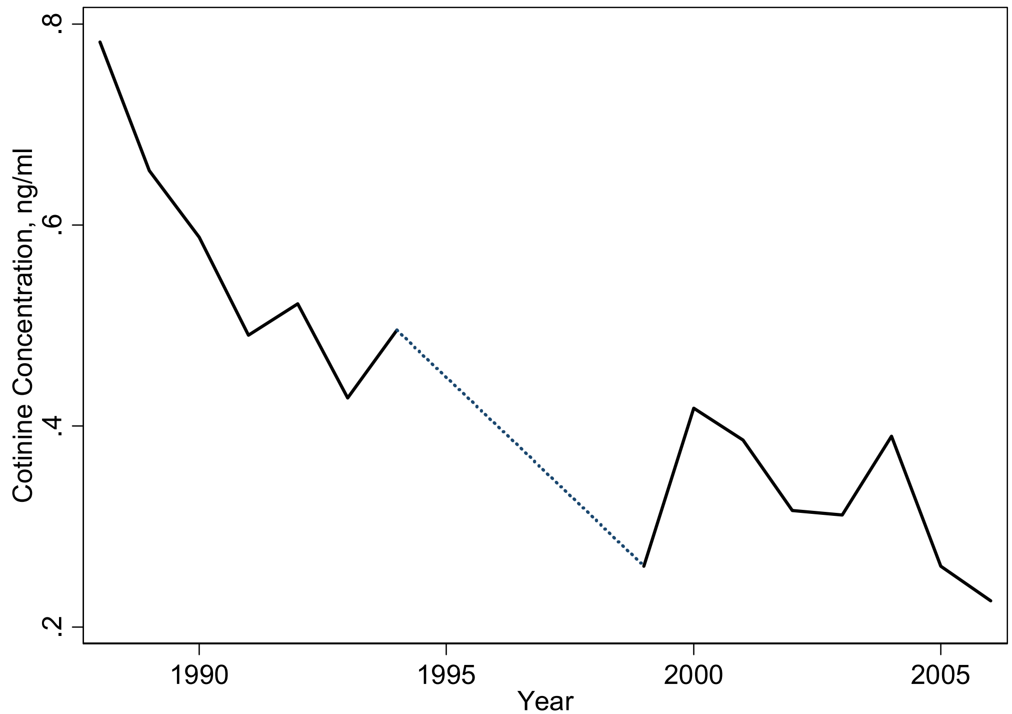

Figure 5: Average Cotinine in Non Smokers from Non Smoking Families

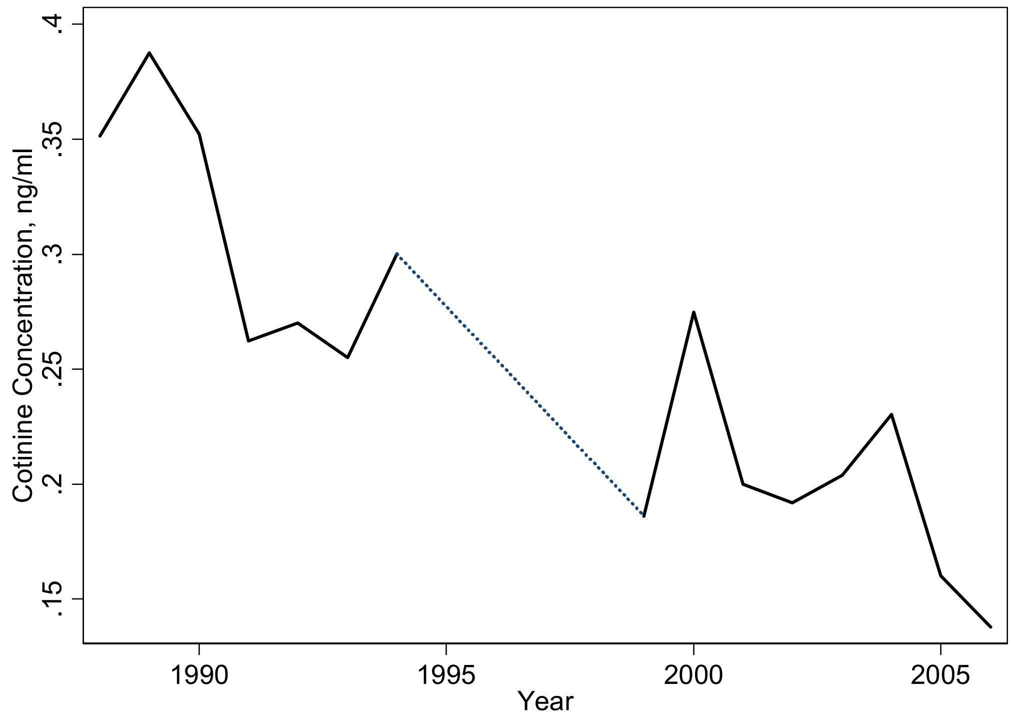

Figure 6: Average Cotinine in Non Smokers from Smoking Families