Access Econ
Scholarly communication without the middle men

Submission Number: PET11-11-00178

Economics of smoking bans

Charles De bartolome
University of Colorado

Ian Irvine
Concordia University

Abstract

We use cigarettes as our motivating example of a product of which the government wishes to reduce the consumption. The government has two possible policies - increasing the price (imposing a tax) or limiting when the product can be consumed (imposing a ban on smoking in the workplace). The government ability to reduce smoking by increasing the tax is limited by the ability of the smoker to buy illegal but untaxed cigarettes on the black market. We show that the optimal policy is a combination policy of tax plus ban.

Submitted: March 02, 2011.

THE ECONOMICS OF SMOKING BANS

by

Charles A.M. de Bartolome
University of Colorado, *Boulder, Colorado, USA*

and

Ian J. Irvine
Concordia University, Montreal, Canada

ABSTRACT

We use cigarettes as our motivating example of a product of which the government wishes to reduce the consumption. The government has two possible policies - increasing the price (imposing a tax) or limiting when the product can be consumed (imposing a ban on smoking in the workplace). The government ability to reduce smoking by increasing the tax is limited by the ability of the smoker to buy illegal but untaxed cigarettes on the black market. We show that the optimal policy is a combination policy of tax plus ban.

Key words: smoking, ban, government control.

Suggested running title: Smoking Bans

Address for correspondence: Charles A.M. de Bartolome, Department of Economics, University of Colorado, 256 UCB, Boulder, CO 80309-0256, USA. email: debartol@colorado.edu

1. INTRODUCTION

Many jurisdictions - at the local level and at the state/provincial level - ban smoking in the workplace. Evans, Farrelly and Montgomery (1999) estimate that 70% of US workers work in firms which ban smoking in the workplace, and that such bans reduce smoking participation by 5% and reduce the cigarettes consumer by a smoker by 10%. This paper seeks to answer two related questions: is the ban "good" policy? and why does the ban reduce smoking?

Concerning policy. Economists have long been interested in policy issues in which households make inefficient choices. A well-researched example is pollution in which an individual considers only her own benefit from her action and ignores the consequences of her action on others. An important policy issue is whether the individual's action is better controlled indirectly by changing the price (usually implemented by imposing a tax) or directly by limiting the quantity of the activity. Our research considers the case of the smoking of cigarettes which the government wishes to limit because of the ill-health it causes. If the government uses a price policy to reduce smoking, it levies a tax on cigarettes. However, the ability of the government to increase the tax on cigarettes to punitive levels is limited by the ability of the smoker to buy illegal but untaxed cigarettes.[1] Another possible policy of the government is to ban smoking in the workplace, which might be considered a quantity policy. In our model in which the government's use of taxes is limited, we show that the best policy is always a combination policy of tax plus ban.

The workplace ban reduces smoking because of the addictive nature of cigarettes. The traditional discussion of addiction (e.g. Becker and Murphy (1988)) focuses on long-run or between-period addiction which causes the consumption of cigarettes in one period to depend on the smoker's past history of smoking. Instead, we focus on a short-run or within-period addiction which causes the smoker to prefer a steady flow of cigarettes to an unsteady flow. In particular, as a cigarette is smoked, a shot of nicotine is introduced into the blood, providing stimulation to the smoker. As the day moves forward, the nicotine metamorphoses into continine and the nicotine in the blood declines. This decline produces a strong longing by the smoker to restore the nicotine to its pre-existing level, inducing the smoker to want to light up another cigarette. Overall, the smoker tries to keep a steady flow of nicotine in the blood, which we model as a dislike of variance. A smoking ban works because, if the smoker tries to replace the cigarettes he previously smoked in the workplace by additional cigarettes smoked at home - in the morning before leaving for work and in the evening after returning from work - the variance increases, making such substitution less beneficial.

We use smoking as our motivating example but we believe that the theory may be applied in many cases in which the government considers the product to be "a bad" (rather than a "good") and wishes to limit the extent to which the product is consumed. In addition to smoking bans at the workplace (or at restaurants or other public places), our theory explains licensing laws which limit alcohol purchases to particular times; the ceiling placed on bets at some casinos (here varying the bet adds to the "thrill" so limiting the variance makes gambling less attractive); and laws which criminalize drugs, making their supply uncertain.

We believe our model is more general than the specific assumptions we make. In our model, addiction is modeled as a dislike of daily variance. In the classic "rational addiction" model of Becker and Murphy (1988), addiction implies that the utility flow from consumption depends on the accumulated stock of past consumption. Our model, by taking a short-run perspective in which the past history is taken as given, ignores this important aspect of addiction. However, our results are suggestive of long-run gains. A workplace ban, by increasing the daily variance, makes smoking less attractive every day; therefore less cigarettes are smoked in each period, decreasing the accumulated stock of past consumption evaluated at a future date and improving future health.

In our model the government is paternalistic and wants to limit smoking because smokers incorrectly perceive the ill-effects of smoking on their health. Of course there are other reasons the government may wish to limit smoking, prominent among them being the externality created by "second-hand" smoke. There is also the possibility that smokers suffer from time inconsistency (Gruber and Koszegi (2004)), or that there is a projection bias (O'Donohue and Rabin (2001)) or that smokers are exposed to the wrong type of cue (Bernheim and Rangell (2004)). Introducing this type of motivation would complicate our model but we do not believe it would change our results; what is important in our model is that the smoker dislikes variance and that the government wants to limit smoking. Finally, we use the possibility of smokers switching to untaxed but illegal cigarettes as a device to limit the ability of the government to tax cigarettes. Another model might have political reasons or tax competition (as in de Bartolome (2007)) preventing the government from setting taxes which are arbitrarily high. The devise itself is not important; what is important is that the government is unable to completely eliminate smoking by setting a punitive tax rate.

The paper is organized as follows. Section 2 summarizes the literature on smoking bans. Section 3 introduces the model by describing an individual's smoking decision and the reason for government's concern over the smoking level. Section 4 shows the effect of a smoking ban when cigarettes are untaxed. Section 5 shows how the potential to buy untaxed but illegal cigarettes limits the government's ability to reduce smoking using the tax instrument alone. Section 6 undertakes a positive discussion when the government simultaneously uses a tax and a smoking ban. Section 7 shows that the smoking ban is always a useful instrument by which to control smoking, even when the tax can be set optimally. Section 8 discusses the long-run consequences of a ban. Section 9 concludes

2. LITERATURE ON GOVERNMENT POLICY TOWARDS SMOKING

Bans on the use of tobacco in public and work places are widespread in all developed economies at the present time. They take many forms and are enacted by municipal, state/provincial and federal governments. They extend not only to the workplace, but also to the five B's (bars, bingo halls, bowling alleys, betting establishments, and billiard halls). Local governments frequently impose more restrictions than are required by higher-level legislation.

Prior to the 1990s, taxes were the main instrument by which governments sought to reduce tobacco use. Some of the earliest municipal ordinances were enacted in California around 1990 (see Moskowitz et al, 2000). The modern era has seen governments develop a larger array of anti-tobacco armaments: in addition to bans, health warnings on tobacco packages now appear in many countries, advertising of tobacco products has been severely curtailed; sponsorship of sports events by tobacco companies has been restricted and store displays have been outlawed.

In part bans have been introduced out of the recognition that the effectiveness of ever higher taxes is limited, on account of the incentive these latter provide for illegal production and trans-border shipment. For example, as of end 2007, approximately one third of cigarettes sold in Canada were supplied illegally.[2] Additionally, bans are seen as a distinct measure in the fight against tobacco use, a measure that impacts the user in a different manner and that can therefore supplement the role of price disincentives. The group of non-price disincentives noted above form what is now termed the public health move to 'denormalize' smoking.

A substantive empirical literature documents the impact of smoking bans, and many econometric papers that estimate the impact of tax/price measures attempt to control for the impact of bans. Numerous studies have found lower tobacco prevalence and quantity in workplaces covered by complete or partial bans (Chapman *et al*, 1999, Fichtenberg and Glantz, 2002, or Gagné, 2008). While such correlations could reflect a choice of workplace in a high labor turnover economy, Evans, Farrelly and Montgomery (1998) controlled for the possible endogeneity of the choice of work place, and still found that bans reduced tobacco use. Furthermore, Cutler and Glaeser (2007) propose that smoking reductions achieved through bans may have a social multiplier impact.

While health groups universally support the implementation and extension of strictures on smoking, some research has been less than fully supportive. For example, Adams and Cotti (2008) propose that bans in bars have been found to encourage patrons to seek out bars in adjoining jurisdictions where smoking is not banned, with the consequence that road and vehicle accident rates increase as a result of driving further under the influence of some amount of alcohol.

The strength of bans (and the level of taxes) varies widely, depending upon the degree of anti-tobacco 'sentiment' in the jurisdiction in question (e.g. deCicca et al 2006). Sentiment against tobacco control is stronger in states or regions where tobacco is grown. For example, Kentucky and the Carolinas have lower tax rates on cigarettes than Massachusetts, because tobacco is a means of livelihood for many in the former states. At the same time, anti-tobacco sentiment may translate into more widespread bans on public place use.

Public policy interventions against smoking have received support from several recent theoretical developments that have addressed the implications of deviations from the assumptions of the traditional utility-maximizing model: Gruber and Koszegi and O' Donohue and Rabin have developed policy measures based on models of time inconsistent behavior and projection bias respectively, while Bernheim and Rangel have developed a framework in which environmental cues are capable of triggering mistakes on the part of the brain's decision mechanism. In the case of time inconsistency, problems arise because it is only in future periods that the negative consequences of current actions materialize, and a high discount rate that applies to immediate decisions undervalues those consequences relative to a lower long-run discount rate. With projection bias, users miscalculate the future negative impacts associated with today's consumption. In the case of cues or stimuli that promote particular actions, the brain can err in its decision making, and therefore the elimination of certain environmental cues (such as the advertising of toxic products) can reduce errors and increase well being. These models stand in contrast to the rational addiction model of Becker and Murphy, and Becker, Grossman and Murphy (1994), described above.

A critical element in smoking bans is the degree to which they induce substitution in time-of-day smoking: if individuals are restricted in the hours during which they are permitted to smoke, do such restrictions imply that smoking will fall (roughly) in line with the reduction in the proportion of the day during which smoking is not permitted? Or will substitution take place towards other non-restricted times of the day? Adda and Cornaglia (2007) propose that public-place smoking bans have led to an increase in the amount of smoking in the home, and that this in turn has increased the amount of second-hand smoke to which children and other non-smokers are exposed. Thus, substitution possibilities are critical. The model we develop in the next section permits smokers to increase their nicotine intake during non-restricted periods of the day in response to the imposition of a workplace ban.

3. THE MODEL

We introduce our model by considering the case when the government potentially imposes a tax on cigarettes but there is no ban. Smoking is addictive in both the long-run and in the short-run. The long-run effect is modeled by Becker and Murphy (1988); an individual's utility from smoking in any day is affected by the individual's prior smoking history . While recognizing the long-run effect, we choose to focus on the short-run or within-the-day effect for which the smoking history is pre-determined.

We consider a day to have 3 periods; descriptively, the first period is the morning period before the individual goes to work, the second period is the period during which the individual works and the third period is the period after work. The consumption of the numeraire in the day is x and cigarette consumption in Period *1* is c_1, in Period 2 is c_2 and in Period 3 is c_3 .The individual's utility in any day depends on x, c_1, c_2, c_3, on his perceived health h , or is $U(x, c_1, c_2, c_3, h)$. We assume a specific form for this function, viz.

$$U(x, c_1, c_2, c_3, h) = x + V(c_1, c_2, c_3) + h(c_1, c_2, c_3).$$

The term $V(c_1, c_2, c_3)$ represents the direct utility the individual achieves from smoking the cigarettes c_1, c_2 and c_3 . As noted in the Introduction, the smoker prefers a steady level of nicotine in the blood to an unsteady level and this is facilitated by a steady rate of consuming cigarettes. We model this by setting the direct utility of cigarettes to have mean-variance form, with the smoker "enjoying" the mean level of cigarettes and the smoker's preference for a steady consumption of cigarettes being represented as a dislike of variance:

$$V(c_1, c_2, c_3|C) = a(c_1 + c_2 + c_3) - b\,\text{var}(c_1, c_2, c_3)\ .$$

The parameters a and b are positive. In a fuller model with long-run addiction, they could be made functions of the smoking history but, as this history is pre-determined in the short-run, this dependance is suppressed until Section 8.

Any model of smoking with policy implications must explain what seems unexplainable - why people choose to smoke when the induced health risks make it, to most outside observers, such a poor choice. The *true* health H of the smoker is a negative function of the cigarettes he smokes, $H(c_1, c_2, c_3)$,

$$\frac{\partial H}{\partial c_i} < 0$$

However, the ill-health caused by cigarettes occurs in the future and so is not experienced by the individual when making his cigarette choice. In particular, the individual *i perceives* his future health to be:

$$h(c_1, c_2, c_3|\alpha^i) \equiv (1+\alpha^i)H(c_1, c_2, c_3)$$

with

$$\frac{\partial h}{\partial c_i} = (1+\alpha^i)\frac{\partial H}{\partial c_i}\ .$$

ASSUMPTION: The perception parameter α^i *is symmetrically distributed on [-1, +1].*

Individuals are making errors in their perception of the effect of cigarettes on their future health; individuals for whom $\alpha^i < 0$ perceive that the effect of smoking on their future health is less negative than it really is and, as we show later, they are the individuals who smoke.

We model the true relationship between cigarettes smoked and health to have quadratic form

$$H = -s(c_1 + c_2 + c_3) - t(c_1 + c_2 + c_3)^2$$

where the negative signs indicate that the health of the smoker declines with the cigarettes he smokes. The perceived health of the individual *i* is therefore

$$h = -(1+\alpha^i)(s(c_1 + c_2 + c_3) + t(c_1 + c_2 + c_3)^2).$$

The parameters *s* and *t* are assumed to be positive. In a fuller model with long-run addiction, *s* and *t* would be made functions of the individual's smoking history but as this history is pre-determined in the short-run this dependance is suppressed until Section 8.

The individual's income is denoted *M* and the consumer price (which may include a tax) of a cigarette is denoted *q*. The individual potentially receives a lump-sum *R* from the government. Hence $x = M + R - q(c_1 + c_2 + c_3)$. Noting that the variance can be written as $\text{var}(c_1, c_2, c_3) = \frac{2}{9}(c_1^2 + c_2^2 + c_3^2 - c_1c_2 - c_1c_3 - c_2c_3)$, the individual *i*'s problem is:

$$\max_{c_1 \geq 0,\, c_2 \geq 0,\, c_3 \geq 0} M + R - q(c_1 + c_2 + c_3) + a(c_1 + c_2 + c_3) - b\frac{2}{9}(c_1^2 + c_2^2 + c_3^2 - c_1c_2 - c_1c_3 - c_2c_3)$$

$$- (1 + \alpha^i)(s(c_1 + c_2 + c_3) + t(c_1 + c_2 + c_3)^2)$$

The first-order condition for the choice of c_1 is:

$$either\ c_1 = 0 \ \text{ and } \quad -q + a - \frac{2}{9}b(2c_1 - c_2 - c_3) - (1+\alpha^i)(s + 2t(c_1 + c_2 + c_3))\ |_{c_1=0} \leq 0;$$

$$or \quad c_1 > 0 \ \text{ and } \quad -q + a - \frac{2}{9}b(2c_1 - c_2 - c_3) - (1+\alpha^i)(s + 2t(c_1 + c_2 + c_3)) \ = 0\ .$$

Using the symmetry of the problem, $c_1 = c_2 = c_3$ and hence:

$$either\ \ a - (1+\alpha^i)s - q \leq 0 \quad \text{and} \quad c_1 = c_2 = c_3 = 0\ ;$$

$$or \quad a - (1+\alpha^i)s - q > 0 \quad \text{and} \quad c_1 = c_2 = c_3 = \frac{a - (1+\alpha^i)s - q}{6(1+\alpha^i)t}.$$

This is rewritten as:

If $\alpha^i \geq \dfrac{a-s-q}{s}$, the individual does not smoke: $c_1 = c_2 = c_3 = 0$; (1)

If $\alpha^i < \dfrac{a-s-q}{s}$, the individual smokes: $c_1 = c_2 = c_3 = \dfrac{a-(1+\alpha^i)s - q}{6(1+\alpha^i)t} > 0.$ (2)

We denote as $\alpha_1(q)$ the critical value of $\alpha^i(q)$ at which an individual is indifferent between not smoking and buying taxed cigarettes.

DEFINITION: the perception parameter of the individual who is indifferent between not smoking *and smoking taxed cigarettes selling at consumer price q is* $\alpha_1(q)$ *:*

$$\alpha_1(q) = \frac{a - s - q}{s} \ .$$

Individuals with $\alpha^i \geq \alpha_1(q)$ do not smoke and individuals with $\alpha^i < \alpha_1(q)$ smoke. We assume that smoking is a "bad" in the strict sense that an individual who correctly perceives the associated ill-health (i.e. for whom $\alpha^i = 0$) does not choose to smoke even when cigarettes are untaxed or sell at their producer price p, or

$$0 > \alpha_1(p) \, ;$$

or

$$a - s - p < 0 \, .$$

In addition, we want there to be some smokers when cigarettes are sold at their producer price, or

$$-1 < \alpha_1(p) \, ;$$

or

$$a - p > 0.$$

Summarizing, we assume

$$a - s - p < 0 < a - p \quad . \tag{3}$$

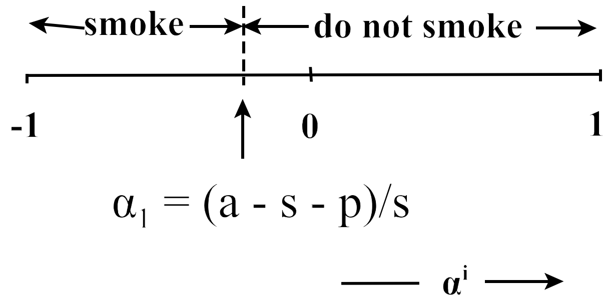

Fig. 1: smoking participation as a function of α^i

Figure 1 summarizes the discussion on how smoking participation varies with the individual's perception parameter α^i. If $\alpha^i = 0$, the individual correctly perceives the effect of cigarettes on his future health and does not smoke. Individuals with $\alpha^i > 0$ perceive the negative effect of smoking on their health to be larger than it really is and do not smoke. Only if α^i is sufficiently negative ($\alpha^i < \alpha_1(q) < 0$) does the individual smoke, perceiving the health effect of smoking to be sufficiently less negative than it really is.

Individuals are making errors in their perceptions. We consider a nice feature of the model to be that, because α^i is symmetrically distributed on [-1,1], the population has no systematic bias in their perceptions. However, because only individuals for whom $\alpha^i \leq \alpha_1(q)$ choose to smoke, smokers are systematically underestimating the ill-effect of smoking on their health.

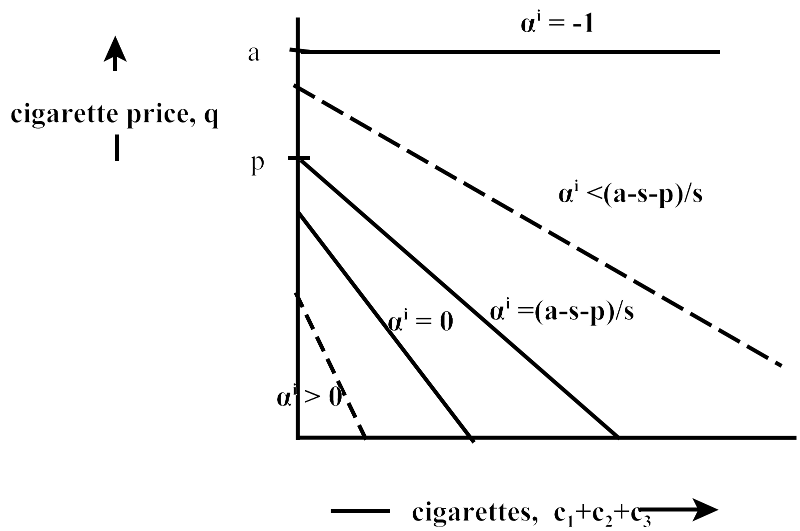

Fig. 2: cigarette demand for individuals with different health perceptions

Figure 2 shows how the demand for cigarettes varies with the perception parameter α^i. From Equation (2), individuals with $\alpha^i = -1$ demand an infinite quantity of cigarettes provided $q < a$, or the demand curve for an individual with parameter $\alpha^i = -1$ is a horizontal line with intercept $q = a$. The demand curve of an individual with parameter $\alpha^i > -1$ is a straight line with price sensitivity

$$\frac{\partial(c_i + c_2 + c_3)}{\partial q} = -\frac{1}{2}\frac{1}{(1+\alpha^i)t} .$$

Remembering that a traditional demand curve is drawn with the price on the vertical axis, the slope of the traditional demand curve is $-2(1+\alpha^i)t$ and the vertical intercept is $a-(1+\alpha^i)s$.

As α^i increases, the demand curve steepens and shifts down. For individuals with $\alpha^i = (a\text{-}s\text{-}p)/s$ the vertical intercept is at p.

4. GOVERNMENT POLICY

The government evaluates individual utility using the true health of the individual or, when its policy is P, it calculates the welfare associated with an individual with perception α^i as:

$$W(\alpha^i,P) \equiv x(\alpha^i,P) + a(c_1(\alpha^i,P) + c_2(\alpha^i,P) + c_3(\alpha^i,P)) - b\,var(c_1(\alpha^i,P),c_2(\alpha^i,P),c_3(\alpha^i,P))$$

$$- (s(c_1(\alpha^i,P) + c_2(\alpha^i,P) + c_3(\alpha^i,P)) + t(c_1(\alpha^i,P) + c_2(\alpha^i,P) + c_3(\alpha^i,P))^2)]$$

where $x(\alpha^i, P)$ is the consumption of numeraire of an individual with perception bias α^i under policy P and $c_1(\alpha^i,P)$ is the consumption of cigarettes in Period 1 of an individual with perception bias α^i, etc. We note that because the government knows the true effect of cigarettes on health, it pre-multiplies health by 1 not $(1+\alpha^i)$. The government calculates social welfare as the sum of all individual "true" utilities under policy P. If α^i is distributed on $[\underline{\alpha},\overline{\alpha}]$ with density $f(\alpha^i)$, social welfare W under policy P is

$$W(P) = \int_{\underline{\alpha}}^{\overline{\alpha}} [\,W(\alpha^i, P) f(\alpha^i) d\alpha^i \tag{3}$$

We normalize the population size to unity. If the government policy is a cigarette tax so that the consumer price is q, all tax revenue is returned as a lump-sum transfer R:

$$R = \int_{\underline{\alpha}}^{\overline{\alpha}} (q - p)(c_1(\alpha^i,q) + c_2(\alpha^i,q) + c_3(\alpha^i,q)) f(\alpha^i)\, d\alpha^i$$

and

$$x(\alpha^i, P) = M + R - q(c_1(\alpha^i, q) + c_2(\alpha^i, q) + c_3(\alpha^i, q)).$$

In this paper we explore three possible government policies:

(1) a smoking ban in Period 2 where Period 2 corresponds to the work period or to the period when smoking by the individual can be monitored. Individuals spend Periods 1 and 3 "at home" where their cigarette consumption cannot be monitored.

(2) a cigarette tax. The government does not know the health perception α^i of the smoker and it does not know the period in which the cigarette is smoked. Therefore all cigarettes must have the same tax.

(3) the combination policy of a cigarette tax plus a smoking ban.

4. SMOKING BAN IN PERIOD 2

In this section we consider the case when the government imposes a smoking ban in Period 2. As the rule setting $c_2 = 0$ is introduced, at the pre-existing levels of c_1 and c_3, there are two effects: (1) the effect of a marginal increase in c_1 or c_3 on health is decreased and (2) the variance is increased. The first effect gives the possibility of the smoker offsetting the ban by substituting into Period 1 or Period 3 cigarettes; the second effect unambiguously lowers cigarette consumption and improves health.[3] This is formalized below.

We assume that there is no tax and hence $q = p$. The individual solves:

$$\max_{c_1 \geq 0,\, c_2 \geq 0,\, c_3 \geq 0} M - p(c_1 + c_2 + c_3) + a(c_1 + c_2 + c_3) - b\frac{2}{9}(c_1^2 + c_2^2 + c_3^2 - c_1c_2 - c_1c_3 - c_2c_3)$$

$$- (1 + \alpha^i)(s(c_1 + c_2 + c_3) + t(c_1 + c_2 + c_3)^2)$$

subject to the smoking ban: $c_2 = 0$;

or, substituting for c_2,

$$\max_{c_1 \geq 0,\, c_3 \geq 0} M - p(c_1 + c_3) + a(c_1 + c_3) - b\frac{2}{9}(c_1^2 + c_3^2 - c_1c_3) - (1 + \alpha)(s(c_1 + c_3) + t(c_1 + c_3)^2).$$

The first-order condition is:

either $c_1 = 0$ and $\quad - p + a - \frac{2}{9}b\left(2c_1 - c_3\right) - (1 + \alpha^i)(s + 2t(c_1 + c_3)) \,|_{c_1 = 0} \leq 0;$

or $\quad c_1 > 0$ and $\quad -p + a - \frac{2}{9}b\left(2c_1 - c_3\right) - (1 + \alpha^i)(s + 2t(c_1 + c_3)) = 0.$

By symmetry, set $c_1 = c_3$; hence

$$\alpha^i \geq \frac{a - s - p}{s} \quad \text{and} \quad c_1 = c_3 = 0$$

or

$$\alpha^i < \frac{a - s - p}{s} \quad \text{and} \quad c_1 = c_3 = \frac{a - (1 + \alpha^i)s - p}{\frac{2}{9}b + 4(1 + \alpha^i)t}$$

We make several observations. First, comparing Equations (1) and (2) with the above, we see that the ban does not change the value of α^i of the marginal smoker who is indifferent between not smoking and smoking, or does not cause any smoker to quit.[4] Why is this? Consider the change in utility from the first cigarette if there is a ban:

$$\frac{\partial U}{\partial c_1}\Big|_{c_1 = 0,\, c_2 = c_3 = 0} = -p + a - (1 + \alpha^i)s.$$

This is the same as if there is no ban. The variance created by the first cigarette is insufficient to deter the smoker. Technically, as $c_1 \to 0$, the variance term is going to zero "too fast". We summarize this observation below:

OBSERVATION 1: *the smoking ban does not cause any smoker to quit*.

The smoking ban in Period 2 may have the unintended consequence of inducing the smoker to increase his smoking in Periods 1 and 3. With no ban, the cigarettes smoked in Period 1 or 3 is:

$$c_1 = c_3 = \frac{a - (1 + \alpha^i)s - p}{6(1 + \alpha^i)t} .$$

With a ban, the cigarettes smoked in Period 1 or 3 is:

$$c_1 = c_3 = \frac{a - (1 + \alpha^i)s - p}{\frac{2}{9}b + 4(1 + \alpha^i)t} .$$

Therefore the ban induces positive substitution into cigarettes in Periods 1 and 3 if:

$$\frac{2}{9}b + 4(1 + \alpha^i)t < 6(1 + \alpha^i)t ;$$

or if

$$b < 9(1 + \alpha^i)t$$

i.e. provided the variance term is not "too strong". We summarize this observation:

OBSERVATION 2: *The smoking ban in Period 2 will increase the number of cigarettes smoked in Periods 1 and 3 unless the dislike of variance is "too strong."*

Another way of seeing the role of variance is to consider the marginal effects. The direct effect of cigarettes is

$$V = a(c_1 + c_2 + c_3) - b\frac{2}{9}(c_1^2 + c_2^2 + c_3^2 - c_1c_2 - c_1c_3 - c_2c_3)$$

and so the marginal effect of increasing cigarettes smoked in the first period is:

$$\frac{\partial V}{\partial c_1} = a - b\frac{2}{9}(2c_1 - c_2 - c_3).$$

Similarly, perceived health is:

$$h = -(1+\alpha^i)(s(c_1 + c_2 + c_3) + t(c_1^2 + c_2^2 + c_3^2 + 2c_1c_2 + 2c_1c_3 + 2c_2c_3)$$

and so the marginal effect of increasing cigarettes smoked in the first period is:

$$\frac{\partial h}{\partial c_1} = -(1+\alpha^i)(s + t(2c_1 + 2c_2 + 2c_3) \quad .$$

If the pre-existing condition is that there is no ban, $c_1 = c_2 = c_3 = c$ and

$$\frac{\partial V}{\partial c_1} = a\,;$$

$$\frac{\partial h}{\partial c_1} = -(1+\alpha^i)(s + 6tc) \quad .$$

If the ban is introduced ($c_2 = 0$) and c_1 and c_3 are held at their pre-existing levels ($c_1 = c_3 = c$)

$$\frac{\partial V}{\partial c_1} = a - b\frac{2}{9}c\,;$$

$$\frac{\partial h}{\partial c_1} = -(1+\alpha^i)(s+4tc)\ .$$

Summarizing, holding c_1 and c_3 at their pre-existing levels, the ban reduces the marginal direct utility of c_1 because of the increasing variance and reduces the marginal perceived health cost. Overall, c_1 increases if the decrease in the marginal perceived health cost is greater than the decrease in the direct utility or if

$$b\frac{2}{9}c < (1+\alpha^i)2tc$$

or if

$$b < 9(1+\alpha^i)t$$

However, the smoking ban lowers the total cigarettes smoked. With no ban, the total cigarettes smoked is:

$$c_1 + c_2 + c_3 = \frac{a-(1+\alpha)s-p}{2(1+\alpha)t}\ ;$$

With a ban, the total cigarettes smoked is:

$$c_1 + c_3 = \frac{a-(1+\alpha)s-p}{\frac{b}{9}+2(1+\alpha)t}\ .$$

Hence, $b > 0$ ensures that the ban lowers the total number of cigarettes smoked by a smoker. This is formalized in the observation below:

OBSERVATION 3: The smoking ban - by increasing the variance - lowers the utility from smoking and reduces the total number of cigarettes smoked by a smoker.

The reduction in total number of cigarettes can also be seen using marginal analysis. If there is no ban and the total number of cigarettes smoked is C, $c_1 = c_2 = c_3 = C/3$ and utility is

$$M + R - pC - (1+\alpha^i)(sC + tC^2)$$

and the marginal utility of an additional cigarette is

$$-p - (1+\alpha^i)(s + 2tC)\,.$$

If the ban is imposed and the total number of cigarettes is held unchanged ($c_2 = 0$, $c_1 = c_3 = C/2$), utility is

$$M + R - pC + aC - b\frac{2}{9}\frac{C^2}{4} - (1+\alpha^i)(sC + tC^2)$$

and the marginal utility of an additional cigarette is

$$-p - b\frac{2}{9}\frac{2C}{4} - (1+\alpha^i)(s + 2tC)\,.$$

The variance associated with the ban decreases the marginal utility of a cigarette and consequently the total number of cigarettes falls.

The smoking ban improves health which increases the welfare of the smoker as calculated by the government. But it increases variance which decreases the smoker's utility and hence the welfare of the smoker as calculated by the government. Proposition 1 shows that the improvement in health dominates.

PROPOSITION 1: the smoking ban increases government welfare

PROOF: see Appendix A.

5. TAX ONLY

The government would like to stop smoking. Using Inequality (2), an individual i buys cigarettes provided $\alpha^i < (a - s - q) / s$. But $-1 \le \alpha^i$. Putting these inequalities together, some individuals are buying cigarettes provided

$$-1 < \frac{a - s - q}{s};$$

or provided

$$q < a. \tag{4}$$

Hence, if the government can impose a sufficiently high tax, it can achieve its objective of stopping smoking. However, we believe that the government is limited in its ability to raise the tax rate and we model this restriction as coming from the possibility of individuals buying untaxed cigarettes on the "black market".

The individual can either buy legal cigarettes at consumer price q, or can buy illegal untaxed cigarettes at a consumer price p. To participate in the illegal market, the individual must pay a fixed cost F.[5] To close the model, any tax collected is returned to all individuals as a lump-sum transfer R.

We now describe the values of α^i as a function of q at which individuals choose not to smoke, to smoke legal cigarettes and to smoke illegal cigarettes. If the individual buys legal cigarettes, the consumer price is q and

$$c_1 = c_2 = c_3 = \frac{a - (1+\alpha)s - q}{6(1+\alpha)t};$$

his utility is:

$$M + R - q3\frac{a-(1+\alpha)s-q}{6(1+\alpha)t} + a3\frac{a-(1+\alpha)s-q}{6(1+\alpha)t} - (1+\alpha)\left(s3\frac{a-(1+\alpha)s-q}{6(1+\alpha)t} + t9\left(\frac{a-(1+\alpha)s-q}{6(1+\alpha)t}\right)^2\right) \quad (5)$$

If the individual buys illegal cigarettes, the consumer price is *p* and

$$c_1 = c_2 = c_3 = \frac{a - (1+\alpha)s - p}{6(1+\alpha)t};$$

he pays a fixed cost *F* (but still receives the lump-sum transfer *R*) and his utility is:

$$M - F + R - p3\frac{a-(1+\alpha)s-p}{6(1+\alpha)t} + a3\frac{a-(1+\alpha)s-p}{6(1+\alpha)t} - (1+\alpha)\left(s3\frac{a-(1+\alpha)s-p}{6(1+\alpha)t} + t9\left(\frac{a-(1+\alpha)s-p}{6(1+\alpha)t}\right)^2\right) \quad (6)$$

DEFINITION: The individual with perception $\alpha_2(q)$ *achieves equal utility by buying in the legal and illegal markets.*

Equating Expressions (5) and (6), we can show

$$\alpha_2(q) = \frac{1}{2}\frac{-q^2 + p^2 + 2(a-s)(q-p) - 4tF}{s(q-p) + 2tF}.$$

When $q = p$, $\alpha_2 = -1$. Differentitating

$$\frac{d\alpha_2}{dq} = \frac{1}{2}\frac{(s(q-p)+2tF)(-2q+2(a-s)) - (-q^2+p^2+2(a-s)(q-p)-4tF)s}{(s(q-p)+2tF)^2}.$$

Imposing the condition $\alpha_2 < \alpha_1$, we can show that

$$\alpha_2 < \alpha_1 \ \text{implies} \ \frac{d\alpha_2}{dq} > 0.$$

Intuitively, as the consumer price increases, more people buy illegal cigarettes. In addition,

$$\alpha_2 = \alpha_1 \ \text{implies} \ \frac{d\alpha_2}{dq} = 0.$$

At $\alpha_2 = \alpha_1$, the consumer price is $\hat{q}$, or

$$-(\hat{q}-p)^2 s + 4tF(a-\hat{q}) = 0,$$

This can be solved to give

$$\hat{q} = p + \frac{-2tF + 2\sqrt{tF(tF+(a-p)s)}}{s}.$$

The associated value of α_2 is

$$\alpha_2(\hat{q}) = \alpha_1(\hat{q}) = \frac{a-s-\hat{q}}{s} = \frac{(a-s-p)s + 2tF - 2\sqrt{tF(tF+(a-p)s)}}{s^2}.$$

At prices exceeding $\hat{q}$, no smokers buy legal cigarettes. The relevant comparison is between not-smoking and smoking illegal cigarettes, and the value of α^i which makes the smoker indifferent between these choices does not depend on *q*.

Pulling this all together, the different α^i, q regions at which individuals do not smoke, smoke legal cigarettes and smoke illegal cigarettes is summarized in Figure 2 below.

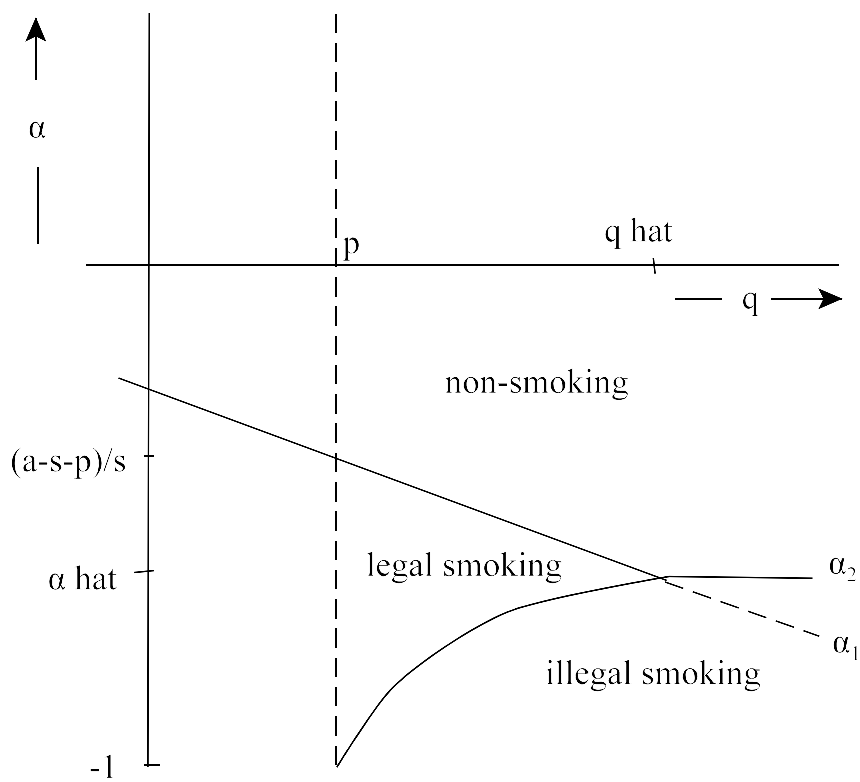

Figure 2: the division of individuals between non-smokers, smokers of legal cigarettes and smokers of illegal cigarettes

It is straight-forward to show that $\hat{q} < a$. Hence Inequality (4) is satisfied or the government is unable to eliminate smoking by raising the tax rate.

6. COMBINATION POLICY OF TAX AND BAN: POSITIVE ANALYSIS

We are interested in comparing the welfare achieved without a smoking ban and with the tax being set optimally to the welfare achieved with a smoking ban and with the tax being set optimally. however, we cannot calculate out the optimal tax rate in closed form. Therefore we proceed using calculus by considering a partial ban in which an individual is allowed to smoke in the second period a fraction θ of the amount he smokes if there is no ban. The analysis then considers the effect of tightening the ban or of lowering θ from 1 to 0.

We consider that an individual who smokes legal cigarettes is restricted to smoke $\bar{c}_2^{legal}$ cigarettes in the second period,

$$\bar{c}_2^{legal} = \theta \frac{a - (1+\alpha)s - q}{6(1+\alpha)t};$$

and an individual smoking illegal cigarettes is restricted to smoke $\bar{c}_2^{illegal}$ cigarettes in the second period,

$$\bar{c}_2^{illegal} = \theta \frac{a - (1+\alpha)s - p}{6(1+\alpha)t}.$$

We note that when $\theta = 1$ it is "as if" the individual is unrestricted or there is no ban, and when $\theta = 0$ the individual is unable to smoke cigarettes in the second period, or the ban is total.

(i) Calculation of utility with legal purchases:

The individual's problem is:

$$\max_{c_1 \geq 0,\, c_3 \geq 0} M + R + (a - (1+\alpha^i)s - q)(c_1 + \overline{c}_2^{legal} + c_3)$$

$$- b\frac{2}{9}(c_1^2 + \overline{c}_2^{legal\,2} + c_3^2 - c_1\overline{c}_2^{legal} - c_1c_3 - \overline{c}_2^{legal}c_3) - (1+\alpha^i)t(c_1 + \overline{c}_2^{legal} + c_3)^2$$

$$\text{s.t. } \overline{c}_2^{legal} = \theta\,\frac{a - (1+\alpha^i)s - q}{6(1+\alpha)t}.$$

The first-order condition for the choice of c_1 is:

either $c_1 = 0$ and

$$(a - (1+\alpha^i)s - q) - b\frac{2}{9}(2c_1 - \theta\frac{a-(1+\alpha^i)s-q}{6(1+\alpha^i)t} - c_3) - (1+\alpha^i)t2(c_1 + \theta\frac{a-(1+\alpha^i)s-q}{6(1+\alpha^i)t} + c_3) \leq 0;$$

or $c_1 > 0$ and

$$(a - (1+\alpha^i)s - q) - b\frac{2}{9}(2c_1 - \theta\frac{a-(1+\alpha^i)s-q}{6(1+\alpha^i)t} - c_3) - (1+\alpha^i)t2(c_1 + \theta\frac{a-(1+\alpha^i)s-q}{6(1+\alpha^i)t} + c_3) = 0.$$

By symmetry, set $c_1 = c_3$, and simplifying

either $a - (1+\alpha^i)s - q \leq 0 : c_1 = c_3 = 0;$

$$or \qquad a-(1+\alpha^i)s-q>0: \quad c_1 = c_3 = \frac{\frac{a-(1+\alpha^i)s-q}{6(1+\alpha^i)t}\left(6(1+\alpha^i)t+\frac{2}{9}b\theta-2(1+\alpha^i)t\theta\right)}{\frac{2}{9}b+4(1+\alpha^i)t}.$$

Substituting into the smoker's utility function, the utility of the legal smoker with perception α^i is:

$$M+R+3(a-(1+\alpha^i)s-q)\frac{(a-(1+\alpha^i)s-q)\left(\frac{2}{9}b\theta+4(1+\alpha^i)t\right)}{6(1+\alpha^i)t\left(\frac{2}{9}b+4(1+\alpha^i)t\right)}$$

$$-b\frac{2}{9}(a-(1+\alpha^i)s-q)^2\frac{(1-\theta)^2}{\left(\frac{2}{9}b+4(1+\alpha^i)t\right)^2}-9(1+\alpha^i)t\,\frac{(a-(1+\alpha^i)s-q)^2}{\left(6(1+\alpha^i)t\right)^2}\frac{\left(\frac{2}{9}b\theta+4(1+\alpha^i)t\right)^2}{\left(\frac{2}{9}b+4(1+\alpha^i)t\right)^2}.(7)$$

(ii) *Calculation of utility with illegal purchases*:

The individual's problem is:

$$\max_{c_1\geq 0,\, c_3\geq 0} M+R-F+(a-(1+\alpha^i)s-p)(c_1+\overline{c}_2^{illegal}+c_3)$$

$$-b\frac{2}{9}(c_1^2+\overline{c}_2^{illegal\,2}+c_3^2-c_1\overline{c}_2^{illegal}-c_1c_3-\overline{c}_2^{illegal}c_3)-(1+\alpha^i)t(c_1+\overline{c}_2^{illegal}+c_3)^2$$

s.t. $\overline{c}_2^{illegal} = \theta\,\frac{a-(1+\alpha^i)s-p}{6(1+\alpha)t}$.

After simplification, the first-order condition for the choice of c_1 is:

either $c_1 = 0$ and

$$(a-(1+\alpha^i)s-p) - b\frac{2}{9}(2c_1 - \theta\frac{a-(1+\alpha^i)s-p}{6(1+\alpha^i)t} - c_3) - (1+\alpha^i)t2(c_1 + \theta\frac{a-(1+\alpha^i)s-p}{6(1+\alpha^i)t} + c_3) \le 0;$$

or $c_1 > 0$ and

$$(a-(1+\alpha^i)s-p) - b\frac{2}{9}(2c_1 - \theta\frac{a-(1+\alpha^i)s-p}{6(1+\alpha^i)t} - c_3) - (1+\alpha^i)t2(c_1 + \theta\frac{a-(1+\alpha^i)s-p}{6(1+\alpha^i)t} + c_3) = 0.$$

By symmetry, set $c_1 = c_3$, and hence

either $a-(1+\alpha^i)s-p \le 0$ and $c_1 = c_3 = 0$

or $a-(1+\alpha^i)s-p > 0$ and $c_1 = \dfrac{\dfrac{a-(1+\alpha^i)s-p}{6(1+\alpha^i)t}\left(6(1+\alpha)t + \dfrac{2}{9}b\theta - 2(1+\alpha^i)t\theta\right)}{\dfrac{2}{9}b + 4(1+\alpha^i)t}$

Hence the utility of the illegal smoker with perception α is:

$$M + R - F + 3(a-(1+\alpha^i)s-p)\frac{(a-(1+\alpha^i)s-p)\left(\frac{2}{9}b\theta + 4(1+\alpha^i)t\right)}{6(1+\alpha^i)t\left(\frac{2}{9}b + 4(1+\alpha^i)t\right)}$$

$$-b\frac{2}{9}(a-(1+\alpha^i)s-p)^2\frac{(1-\theta)^2}{\left(\frac{2}{9}b + 4(1+\alpha^i)t\right)^2} - 9(1+\alpha^i)t\frac{(a-(1+\alpha^i)s-p)^2}{(6(1+\alpha^i)t)^2}\frac{\left(\frac{2}{9}b\theta + 4(1+\alpha^i)t\right)^2}{\left(\frac{2}{9}b + 4(1+\alpha^i)t\right)^2}. \quad (8)$$

(iii) *Calculation of* α_1

Using Equation (7), the individual with perception parameter α_1 achieves the same utility from smoking legal cigarettes as from not smoking when:

$$M + R + 3(a - (1+\alpha_1)s - q)\frac{(a - (1+\alpha_1)s - q)\left(\frac{2}{9}b\theta + 4(1+\alpha_1)t\right)}{6(1+\alpha_1)t\left(\frac{2}{9}b + 4(1+\alpha_1)t\right)}$$

$$- b\frac{2}{9}(a-(1+\alpha_1)s-q)^2\frac{(1-\theta)^2}{\left(\frac{2}{9}b+4(1+\alpha_1)t\right)^2} - 9(1+\alpha_1)t\frac{(a-(1+\alpha_1)s-q)^2}{\left(6(1+\alpha_1)t\right)^2}\frac{\left(\frac{2}{9}b\theta + 4(1+\alpha_1)t\right)^2}{\left(\frac{2}{9}b + 4(1+\alpha_1)t\right)^2} = M + R;$$

Solving:

$$\alpha_1 = \frac{a - s - q}{s}.$$

(iv) Calculation of α_2.

Using Equations (7) and (8), the individual with perception parameter α_2 achieves the same utility from smoking legal and illegal cigarettes when:

$$M + R + 3(a - (1+\alpha_2)s - q)\frac{(a - (1+\alpha_2)s - q)\left(\frac{2}{9}b\theta + 4(1+\alpha_2)t\right)}{6(1+\alpha_2)t\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)}$$

$$- b\frac{2}{9}(a - (1+\alpha_2)s - q)^2\frac{(1-\theta)^2}{\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)^2} - 9(1+\alpha_2)\,t\,\frac{(a - (1+\alpha_2)s - q)^2}{\left(6(1+\alpha_2)t\right)^2}\frac{\left(\frac{2}{9}b\theta + 4(1+\alpha_2)t\right)^2}{\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)^2}$$

$$= M + R - F + 3(a - (1+\alpha_2)s - p)\frac{(a - (1+\alpha_2) - p)\left(\frac{2}{9}b\theta + 4(1+\alpha_2)t\right)}{6(1+\alpha_2)t\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)}$$

$$- b\frac{2}{9}(a - (1+\alpha_2)s - p)^2\frac{(1-\theta)^2}{\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)^2}$$

$$- 9(1+\alpha_2)\,t\frac{(a - (1+\alpha_2)s - p)^2}{\left(6(1+\alpha_2)t\right)^2}\frac{\left(\frac{2}{9}b\theta + 4(1+\alpha_2)t\right)^2}{\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)^2}.$$

The above equation may be simplified to:

$$2(1+\alpha_2)t\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)F - \left(2(q-p)(a-(1+\alpha_2)s) - q^2 + p^2\right)\left(2(1+\alpha_2)t + \frac{2}{9}b\theta - \frac{b}{9}\theta^2\right) = 0. \quad (9)$$

Equation (9) is a quadratic equation in $1 + \alpha_2$ which can be solved. We note:

(1) when q = p, this equation reduces to:

$$(1+\alpha_2)t\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)F = 0.$$

But $\alpha_2 \geq -1$ and hence

$$\frac{2}{9}b + 4(1+\alpha_2)t > 0.$$

Therefore when $q = p$, $\alpha_2 = -1$.

(2) If θ is held constant, differentiate Equation (9) with respect to q and rearrange

$$\frac{\partial\alpha_2}{\partial q} = \frac{2\left(2(1+\alpha_2)t + \frac{2}{9}b\theta\left(1-\frac{\theta}{2}\right)\right)(a-(1+\alpha_2)s-q)}{(1+\alpha_2)8t^2F + \left(\frac{2}{9}b+4(1+\alpha_2)t\right)2tF - (2(q-p)(a-(1+\alpha_2)s)-q^2+p^2)2t}$$

$$+\left(2(1+\alpha_2)t + \frac{2}{9}b\theta\left(1-\frac{\theta}{2}\right)\right)2(q-p)s.$$

If

$$\alpha_2 < \alpha_1 = \frac{a - s - q}{s} \ ,$$

then $a - (1 + \alpha_2)s - q > 0$. This and $\alpha_2 \geq -1$ and $\theta \leq 1$ implies

$$-1 \leq \alpha_2 < \alpha_1 \quad : \quad \frac{\partial \alpha_2}{\partial q} > 0 \ .$$

When $\alpha_2 = \alpha_1$, $a - (1 + \alpha_2)s - q = 0$ (the legal smoker would smoke no cigarettes) and

$$-1 < \alpha_2 = \alpha_1 \quad : \quad \frac{\partial \alpha_2}{\partial q} = 0 \ .$$

At larger values of q, the relevant boundary is between the non-smoker and the smoker of illegal cigarettes.

(3) If q is held constant, differentiate Equation (9) with respect to θ and rearrange:

$$\frac{\partial \alpha_2}{\partial \theta} = \frac{\left(2(q-p)(a-(1+\alpha_2)s) - q^2 + p^2\right)\frac{2}{9}b(1-\theta)}{(1+\alpha_2)8t^2F + \left(\frac{2}{9}b + 4(1+\alpha_2)t\right)2tF - (2(q-p)(a-(1+\alpha_2)s) - q^2 + p^2)2t}$$

$$+ \left(2(1+\alpha_2)t + \frac{2}{9}b\theta\left(1 - \frac{\theta}{2}\right)\right)2(q-p)s \ .$$

Setting $\theta = 1$:

$$\frac{\partial \alpha_2}{\partial \theta} \Big|_{\theta = 1} = 0;$$

with no ban, the individual, whether smoking legal or illegal cigarettes, is indifferent to the last cigarette smoked and hence his utility is unchanged (to a first-order) if the ban is marginally tightened If $\alpha_2 = -1$, $q = p$ and

$$\frac{\partial \alpha_2}{\partial \theta} \Big|_{\alpha_2 = -1} = 0;$$

with q=p, the ban affects the legal and illegal smoker equally so the boundary between the legal and illegal smoker does not change. More generally we can show that

if either $\theta = 1$ or $\alpha_2 = -1$: $\frac{\partial \alpha_2}{\partial \theta} = 0;$

otherwise: $\frac{\partial \alpha_2}{\partial \theta} > 0.$

Put differently, tightening the ban reduces the number of cigarettes smoked. Hence the pre-existing marginal smoker no longer finds it worthwhile to incur the cost F to buy illegal cigarettes.

Summarizing, Figure 3 shows how α_1 and α_2 vary with q and θ. The figure is drawn with $\theta_2 < \theta_1$.

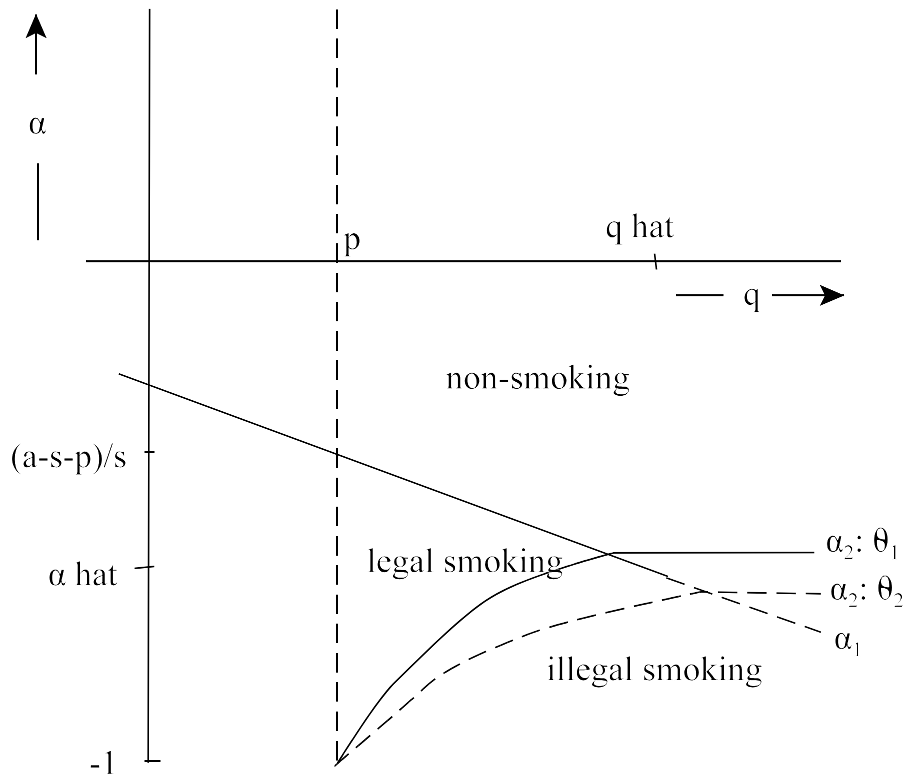

Figure 3: the division of individuals between non-smokers, smokers of legal cigarettes and smokers of illegal cigarettes as the ban in Period 2 is tightened

7. COMBINATION POLICY OF TAX AND BAN: NORMATIVE ANALYSIS

With the government policy P being its choice of q, the consumer price of cigarettes, and θ, the extent of the ban in the second period, the government's problem is to maximize the sum of welfare from smokers of illegal cigarettes, from smokers of legal cigarettes and from non-smokers. We note that without loss of generality we can restrict the government's choice of the consumer price to be between p and $\hat{q}$: if the government sets the consumer price to exceed $\hat{q}$, no legal cigarettes are bought and it is "as if" $q = \hat{q}$. Using Equation (3), the government's problem is:

$$\max_{\substack{p \le q \le \hat{q} \\ 0 \le \theta \le 1}} \int_{-1}^{\alpha_2(q,\theta)} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha \;+\; \int_{\alpha_2(q,\theta)}^{\alpha_1(q)} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha \;+\; \int_{\alpha_1(q)}^{1} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha$$

Instead of calculating the optimum values of q and θ, we instead proceed sequentially. The government is assumed to first choose the optimal consumer price q conditional on θ;

$$W(\theta) \;=\; \max_{p \le q \le \hat{q}} \int_{-1}^{\alpha_2(q,\theta)} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha + \int_{\alpha_2(q,\theta)}^{\alpha_1(q)} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha + \int_{\alpha_1(q)}^{1} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha$$

PROPOSITION 2: *With q being set optimally conditional on θ, q(θ),*

$$\frac{dW(\theta)}{d\theta} < 0$$

PROOF: See Appendix B.

Proposition 2 is the central result of this paper. Even when the tax rate can be set optimally, welfare increases when the smoking ban in the second period is tightened from $\theta = 1$ to $\theta = 0$. Put differently, Proposition 2 implies that it is always desirable to have a full ban in the second period, or to set $\theta = 0$.

8. DISCUSSION OF HISTORY- DEPENDENCE

In Section 2 we noted that addiction has both long-term and short-term aspects.[6] Our model focuses on short-run addiction and is static. The long-term addictive properties of smoking imply that an individual's smoking taste at time *T* is heavily dependent on his smoking history. We interpret the state variable $\Psi(T)$ to be the accumulated stock of cigarettes smoked prior to time T; increasing $\Psi(T)$ increases the smoker's taste for cigarettes at time *T* and lowers his health. We suggested that this should be modeled by making the taste parameters *a* and *b*, and the health parameters *s* and *t* increasing functions of $\Psi(T)$. We note in passing that any policy that lowers the cigarettes smoked at time *T* lowers future values of the accumulated stock, thereby lowering $\Psi(T':T'>T)$ and long-run addiction. Put differently, a policy which lowers smoking in the short-run will also be beneficial in the long-run.

9. CONCLUSION

We consider products which the individual wishes to consume evenly during the day and the consumption of which the government wants to stop. An example of such a product is cigarettes. The government is limited in its ability to set tax rates punitively. We show that a ban on the consumption of the product during part of the day, because it increases the individual's variance in consumption, induces the individual to lower his consumption of the product. In addition, although the ban makes the individual worse off, welfare as calculated by the government increases. By showing that a tax plus a ban is the best policy, we hope this finding adds to the "price *v.* quantity" debate on how to best control socially undesirable activities

APPENDIX A: PROOF OF PROPOSITION A

With no ban and no cigarette tax (R= 0) , the welfare of a smoker as calculated by the government is:

$$M - p\frac{a-(1+\alpha^i)s-p}{2(1+\alpha^i)t} + a\frac{a-(1+\alpha^i)s-p}{2(1+\alpha^i)t} - 1\left(s\frac{a-(1+\alpha^i)s-p}{2(1+\alpha^i)t} + t\left(\frac{a-(1+\alpha^i)s-p}{2(1+\alpha^i)t}\right)^2\right).$$

With a ban, the welfare of the smoker as calculated by the government is:

$$M - p\frac{a-(1+\alpha^i)s-p}{\frac{b}{9}+2(1+\alpha^i)t} + a\frac{a-(1+\alpha^i)s-p}{\frac{b}{9}+2(1+\alpha^i)t} - \frac{2}{9}b\left(\frac{a-(1+\alpha^i)s-p}{\frac{2}{9}b+4(1+\alpha^i)t}\right)^2$$

$$-1\left(s\frac{a-(1+\alpha^i)s-p}{\frac{b}{9}+2(1+\alpha^i)t} + t\left(\frac{a-(1+\alpha^i)s-p}{\frac{b}{9}+2(1+\alpha^i)t}\right)^2\right)$$

where the variance is calculated setting $c_1 = c_3$ and $c_2 = 0$. The ban increases the welfare of the individual as calculated by the government as:

$$\Delta U = (a-s-p)\left(\frac{a-(1+\alpha^i)s-p}{\frac{b}{9}+2(1+\alpha^i)t} - \frac{a-(1+\alpha^i)s-p}{2(1+\alpha^i)t}\right) - \frac{2}{9}b\frac{1}{4}\left(\frac{a-(1+\alpha^i)s-p}{\frac{b}{9}+2(1+\alpha^i)t}\right)^2$$

$$-t\left(\left(\frac{a-(1+\alpha^i)s-p}{\frac{b}{9}+2(1+\alpha^i)t}\right)^2 - \left(\frac{a-(1+\alpha^i)s-p}{2(1+\alpha^i)t}\right)^2\right)$$

We note that, when b = 0, $\Delta U = 0$.
And

$$\frac{d\Delta U}{db} = (a-(1+\alpha^i)s-p)\left[-(a-s-p)\frac{1}{\left(\frac{b}{9}+2(1+\alpha^i)t\right)^2}\frac{1}{9}\right.$$

$$+\,(a-(1+\alpha^i)s-p)\left(\frac{b}{18}2\frac{1}{\left(\frac{b}{9}+2(1+\alpha^i)t\right)^3}\frac{1}{9}-\frac{1}{18}\frac{1}{\left(\frac{b}{9}+2(1+\alpha^i)t\right)^2}\right)$$

$$\left.+\,t(a-(1+\alpha^i)s-p)\frac{2}{\left(\frac{b}{9}+2(1+\alpha^i)t\right)^3}\frac{1}{9}\right]$$

$$= \frac{1}{18}\frac{a-(1+\alpha^i)s-p}{\left(\frac{b}{9}+2(1+\alpha^i)t\right)^3}$$

$$\left[-2(a-s-p)\left(\frac{b}{9}+2(1+\alpha^i)t\right) + (a-(1+\alpha^i)s-p)\left(\frac{2}{9}b-\left(\frac{b}{9}+2(1+\alpha^i)t\right)+4t\right)\right]$$

$$> 0$$

where the last inequality follows from: $a - s - p < 0$; we are considering a smoker or $a - (1 + \alpha^i)\, s - p > 0$ and

$$\frac{2}{9}b - \frac{b}{9} - 2(1+\alpha^i)t + 4t = \frac{b}{9} + 2t(1-\alpha^i) > 0$$

and the last inequality follows that fact that *for a smoker* $\alpha^i \le 0$.

APPENDIX B: PROOF OF PROPOSITION 2

$$W(\theta) \;=\; \max_{p \le q \le \hat{q}} \int_{-1}^{\alpha_2(q,\theta)} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha$$

$$+ \int_{\alpha_2(q,\theta)}^{\alpha_1(q)} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha + \int_{\alpha_1(q)}^{1} W(\alpha, P=(q,\theta)) f(\alpha)\, d\alpha .$$

To evaluate $dW(\theta)/d\theta < 0$ we use the envelope condition:

$$\frac{dW(q(\theta),\theta)}{d\theta} \;=\; \frac{\partial W(q(\theta),\theta)}{\partial\theta}$$

$$= \int_{-1}^{\alpha_2(q,\theta)} \frac{\partial W(\alpha, P=(q,\theta))}{\partial\theta} f(\alpha)\, d\alpha \;+\; W(\alpha_2, P=(q,\theta), illegal) f(\alpha_2) \frac{\partial\alpha_2}{\partial\theta}$$

$$+ \int_{\alpha_2(q,\theta)}^{\alpha_1(q)} \frac{\partial W(\alpha, P=(q,\theta))}{\partial\theta} f(\alpha)\, d\alpha \;-\; W(\alpha_2, P=(q,\theta), legal) f(\alpha_2) \frac{\partial\alpha_2}{\partial\theta}$$

$$+ \int_{\alpha_1(q)}^{1} \frac{\partial W(\alpha, P=(q,\theta))}{\partial\theta} f(\alpha)\, d\alpha$$

where we note α_1 is a function of q but not of θ per se, and hence $\partial\alpha_1(q)/\partial\theta = 0$.

Evaluating each term:

(1) the contribution to welfare for the smoker of illegal cigarettes is:

$$-1 \le \alpha \le \alpha_2: \quad W(\alpha, P=(q,\theta)) \;=\; M + R - F + 3(a - s - p) \frac{(a - (1+\alpha)s - p)\left(\frac{2}{9}b\theta + 4(1+\alpha)t\right)}{6(1+\alpha)t\left(\frac{2}{9}b + 4(1+\alpha)t\right)}$$

$$- b\frac{2}{9}(a - (1+\alpha)s - p)^2 \frac{(1-\theta)^2}{\left(\frac{2}{9}b + 4(1+\alpha)t\right)^2}$$

$$- 9t\frac{(a-(1+\alpha)s-p)^2}{(6(1+\alpha)t)^2}\frac{\left(\frac{2}{9}b\theta + 4(1+\alpha)t\right)^2}{\left(\frac{2}{9}b + 4(1+\alpha)t\right)^2}.$$

This can be simplified to

$$-1 \le \alpha \le \alpha_2 : \ \frac{\partial W(\alpha, P=(q,\theta))}{\partial\theta}$$

$$= \frac{\partial R}{\partial\theta} + \frac{a-(1+\alpha)s-p}{(6(1+\alpha)t)^2\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}\frac{2}{9}b\left(3(a-s-p)6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)\right.$$

$$\left. + (a-(1+\alpha)s-p)\ 18t\left(4(1+\alpha)^2t(1-\theta) - \frac{2}{9}b\theta - 4(1+\alpha)t\right)\right)$$

(2) The contribution to welfare from the smoker of legal cigarettes is

$$\alpha_2 \le \alpha \le \alpha_1 : \quad W(\alpha, P=(q,\theta)) = M + R + 3(a-s-q)\frac{(a-(1+\alpha)s-q)\left(\frac{2}{9}b\theta+4(1+\alpha)t\right)}{6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)}$$

$$- b\frac{2}{9}(a-(1+\alpha)s-q)^2\frac{(1-\theta)^2}{\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}$$

$$- 9t\frac{(a-(1+\alpha)s-q)^2}{(6(1+\alpha)t)^2}\frac{\left(\frac{2}{9}b\theta+4(1+\alpha)t\right)^2}{\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}.$$

Differentiating with respect to θ and rearranging

$$\alpha_2 \le \alpha \le \alpha_1 : \ \frac{\partial W(\alpha, P=(q,\theta))}{\partial\theta}$$

$$= \frac{\partial R}{\partial\theta} + \frac{a-(1+\alpha)s-q}{(6(1+\alpha)t)^2\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}\frac{2}{9}b\left(3(a-s-q)6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)\right.$$

$$\left. + (a-(1+\alpha)s-q)\ 18t\left(4(1+\alpha)^2t(1-\theta) - \frac{2}{9}b\theta - 4(1+\alpha)t\right)\right)$$

(3)To determine $W(\alpha_2, illegal) - W(\alpha_2, legal)$. Substituting for $c_1^{illegal}, \bar{c}_2^{illegal}$ and $c_3^{illegal}$ to determine $W(\alpha_2, illegal)$, and for $c_1^{legal}, \bar{c}_2^{legal}$ and c_3^{legal} to determine $W(\alpha_2, legal)$, we determine after rearrangement

$$W(\alpha_2, illegal) - W(\alpha_2, legal)$$

$$= 3\alpha_2 s\big((a-(1+\alpha_2)s-p)-(a-(1+\alpha_2)s-q)\big)\frac{\left(\frac{2}{9}b\theta+4(1+\alpha_2)t\right)}{6(1+\alpha_2)t\left(\frac{2}{9}b+4(1+\alpha_2)t\right)}$$

$$+ 9\alpha_2 t\frac{(a-(1+\alpha)s-p)^2-(a-(1+\alpha)s-q)^2}{(6(1+\alpha)t)^2}\frac{\left(\frac{2}{9}b\theta+4(1+\alpha)t\right)^2}{\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}.$$

(4) The non-smoker is affected by the change in θ only because the size of his transfer R is affected:

$$\alpha_1 \le \alpha \le 1 \ : \quad \frac{\partial W(\alpha, P = (q,\theta))}{\partial \theta} = \frac{\partial R}{\partial \theta}$$

Hence:

$$\frac{dW(\theta)}{d\theta} = \int_{-1}^{\alpha_2} \Bigg[\frac{\partial R}{\partial \theta} + \frac{a - (1+\alpha)s - p}{(6(1+\alpha)t)^2 \left(\frac{2}{9}b + 4(1+\alpha)t \right)^2} \frac{2}{9} b \Bigg(3(a - s - p) 6(1+\alpha)t \left(\frac{2}{9}b + 4(1+\alpha)t \right)$$

$$+ (a - (1+\alpha)s - p)\, 18t \left(4(1+\alpha)^2 t(1-\theta) - \frac{2}{9} b\theta - 4(1+\alpha)t \right) \Bigg) \Bigg] f(\alpha)\, d\alpha$$

$$\int_{\alpha_2}^{\alpha_1} \Bigg[\frac{\partial R}{\partial \theta} + \frac{a - (1+\alpha)s - q}{(6(1+\alpha)t)^2 \left(\frac{2}{9}b + 4(1+\alpha)t \right)^2} \frac{2}{9} b \Bigg(3(a - s - q) 6(1+\alpha)t \left(\frac{2}{9}b + 4(1+\alpha)t \right)$$

$$+ (a - (1+\alpha)s - q)\, 18t \left(4(1+\alpha)^2 t(1-\theta) - \frac{2}{9} b\theta - 4(1+\alpha)t \right) \Bigg) \Bigg] f(\alpha)\, d\alpha$$

$$+ \Bigg(3\alpha_2 s \big((a - (1+\alpha_2)s - p) - (a - (1+\alpha_2)s - q) \big) \frac{\left(\frac{2}{9} b\theta + 4(1+\alpha_2)t \right)}{6(1+\alpha_2)t \left(\frac{2}{9}b + 4(1+\alpha_2)t \right)}$$

$$+ 9\alpha_2 t \frac{(a - (1+\alpha)s - p)^2 - (a - (1+\alpha)s - q)^2}{(6(1+\alpha)t)^2} \frac{\left(\frac{2}{9}b\theta + 4(1+\alpha)t\right)^2}{\left(\frac{2}{9}b + 4(1+\alpha)t\right)^2} \Bigg) f(\alpha_2) \frac{\partial \alpha_2}{\partial \theta}$$

$$+ \int_{\alpha_1}^{1} \frac{\partial R}{\partial \theta} f(\alpha)\, d\alpha \ .$$

But with the population normalized to unity,

$$\int_{-1}^{\alpha_2} \frac{\partial R}{\partial \theta} f(\alpha)\, d\alpha \ + \int_{\alpha_2}^{\alpha^1} \frac{\partial R}{\partial \theta} f(\alpha)\, d\alpha \ + \int_{\alpha_1}^{1} \frac{\partial R}{\partial \theta} f(\alpha)\, d\alpha \ = \frac{\partial R}{\partial \theta}$$

Tax revenue is:

$$R = \int_{\alpha_2(q,\theta)}^{\alpha_1(q)} (q - p)\, 3 \, \frac{(a - (1+\alpha)s - q)\left(\frac{2}{9}b\theta + 4(1+\alpha)t\right)}{6(1+\alpha)t\left(\frac{2}{9}b + 4(1+\alpha)t\right)} f(\alpha)\, d\alpha$$

and hence

$$\frac{\partial R}{\partial \theta} = \int_{\alpha_2(q,\theta)}^{\alpha_1(q)} 3\,(q - p) \frac{(a - (1+\alpha)s - q)}{6(1+\alpha)t\left(\frac{2}{9}b + 4(1+\alpha)t\right)} \frac{2}{9} b\, f(\alpha)\, d\alpha$$

$$- 3\,(q - p) \frac{(a - (1+\alpha_2)s - q)\left(\frac{2}{9}b\theta + 4(1+\alpha_2)t\right)}{6(1+\alpha_2)t\left(\frac{2}{9}b + 4(1+\alpha_2)t\right)} f(\alpha_2) \frac{\partial \alpha_2}{\partial \theta} \ .$$

Substituting into $dW(\theta)/d\theta$ and rearranging terms:

$$\frac{dW(\theta)}{d\theta} = \int_{-1}^{\alpha_2} \frac{a-(1+\alpha)s-p}{(6(1+\alpha)t)^2\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}\frac{2}{9}b\left(3(a-s-p)6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)\right.$$

$$\left.+(a-(1+\alpha)s-p)\,18t\left(4(1+\alpha)^2t(1-\theta)-\frac{2}{9}b\theta-4(1+\alpha)t\right)\right)f(\alpha)\,d\alpha$$

$$+\int_{\alpha_2}^{\alpha_1} \frac{a-(1+\alpha)s-q}{(6(1+\alpha)t)^2\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}\frac{2}{9}b\left(3(a-s-q)6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)\right.$$

$$\left.+(a-(1+\alpha)s-q)\,18t\left(4(1+\alpha)^2t(1-\theta)-\frac{2}{9}b\theta-4(1+\alpha)t\right)\right)f(\alpha)\,d\alpha$$

$$+\int_{\alpha_2}^{\alpha_1}(q-p)\,3\,\frac{(a-(1+\alpha)s-q)}{6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)}\frac{2}{9}b\,f(\alpha)\,d\alpha$$

$$-3\,(q-p)\,\frac{(a-(1+\alpha_2)s-q)\left(\frac{2}{9}b\theta+4(1+\alpha_2)t\right)}{6(1+\alpha_2)t\left(\frac{2}{9}b+4(1+\alpha_2)t\right)}f(\alpha_2)\frac{\partial\alpha_2}{\partial\theta}\ .$$

$$+\left(3\alpha_2 s\big((a-(1+\alpha_2)s-p)-(a-(1+\alpha_2)s-q)\big)\frac{\left(\frac{2}{9}b\theta+4(1+\alpha_2)t\right)}{6(1+\alpha_2)\,t\left(\frac{2}{9}b+4(1+\alpha_2)t\right)}\right.$$

$$+ 9\alpha_2 t \frac{(a-(1+\alpha)s-p)^2-(a-(1+\alpha)s-q)^2}{(6(1+\alpha)t)^2} \frac{\left(\frac{2}{9}b\theta+4(1+\alpha)t\right)^2}{\left(\frac{2}{9}b+4(1+\alpha)t\right)^2} \Bigg) f(\alpha_2)\frac{\partial \alpha_2}{\partial \theta} .$$

We can sign this as:

1. Knowing that $-1<\alpha\le\alpha_2<0$ implies $a-(1+\alpha)s-p>0$ and that $4(1+\alpha)t>4(1+\alpha)^2t(1-\theta)$; in addition we know $a-s-p<0$. Hence the first integral is negative.

2. Combine the second and third integrals:

$$+\int_{\alpha_2}^{\alpha_1} \frac{a-(1+\alpha)s-q}{(6(1+\alpha)t)^2\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}\frac{2}{9}b\left(3(a-s-q)6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)\right.$$

$$+(a-(1+\alpha)s-q)\,18t\left(4(1+\alpha)^2t(1-\theta)-\frac{2}{9}b\theta-4(1+\alpha)t\right)$$

$$\left.+3\,(q-p)6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)\right) f(\alpha)\,d\alpha$$

$$=\int_{\alpha_2}^{\alpha_1} \frac{a-(1+\alpha)s-q}{(6(1+\alpha)t)^2\left(\frac{2}{9}b+4(1+\alpha)t\right)^2}\frac{2}{9}b\left(3(a-s-p)6(1+\alpha)t\left(\frac{2}{9}b+4(1+\alpha)t\right)\right.$$

$$\left.+(a-(1+\alpha)s-q)\,18t\left(4(1+\alpha)^2t(1-\theta)-\frac{2}{9}b\theta-4(1+\alpha)t\right)\right) f(\alpha)\,d\alpha$$

This is negative because $\alpha_2\le\alpha<\alpha_1<0$ implies that $a-(1+\alpha)s-q>0$ and that $4(1+\alpha)t>4(1+\alpha)^2t(1-\theta)$, and in addition we know that $a-s-p<0$.

3. Combine the last terms:

$$\left(-3\,(q-p)\,\frac{(a-(1+\alpha_2)s-q)\left(\frac{2}{9}b\theta+4(1+\alpha_2)t\right)}{6(1+\alpha_2)t\left(\frac{2}{9}b+4(1+\alpha_2)t\right)} \right.$$

$$+\,3\alpha_2 s\big((a-(1+\alpha_2)s-p)-(a-(1+\alpha_2)s-q)\big)\frac{\left(\frac{2}{9}b\theta+4(1+\alpha_2)t\right)}{6(1+\alpha_2)\,t\left(\frac{2}{9}b+4(1+\alpha_2)t\right)}$$

$$\left. +\,9\alpha_2 t\frac{(a-(1+\alpha_2)s-p)^2-(a-(1+\alpha_2)s-q)^2}{(6(1+\alpha_2)t)^2}\frac{\left(\frac{2}{9}b\theta+4(1+\alpha_2)t\right)^2}{\left(\frac{2}{9}b+4(1+\alpha_2)t\right)^2}\right) f(\alpha_2)\frac{\partial\alpha_2}{\partial\theta}\ .$$

But we know that $a-(1+\alpha_2)s-q>0$; and $q>p$ implies that $a-(1+\alpha_2)s-p>a-(1+\alpha_2)s-q>0$; and $\alpha_2<0$. Hence each term in the brackets is negative. In addition, $\partial\alpha_2/\partial\theta>0$ so that the whole term is negative.

Summarizing,

$$\frac{dW(\theta)}{d\theta}<0$$

REFERENCES

Adams, S. and C. Cotti. "Drunk Driving After the Passage of Smoking Bans in Bars," *Journal of Public Economics*, forthcoming, June 2008.

Adda, J., and F. Cornaglia. "Taxes, Cigarette Consumption and Smoking Intensity." *American Economic Review*, September 2006a, vol. 96(4), 1013-1028.

--------------------------------- "The Effect of Bans and Taxes on Passive Smoking." *University College London and Institute for Fiscal Studies*, October 2006b.

Becker, G. and K. Murphy. "A Theory of Rational Addiction." *Journal of Political Economy*, 1988, 96(4), 675-700.

Becker, G, M. Grossman and K. Murphy. "An Empirical Analysis of Cigarette Addiction." *American Economic Review*, 1994, 84(3), 396-418.

Bernheim, D. and A. Rangel. "From Neuroscience to Public Policy: A new Economic View of Addiction." *Swedish Economic Policy Review*, 2005.

-------------------------- "Addiction and Cue-triggered Decision Processes." *American Economic Review*, 2004, vol. 94, 1558-1590.

Chapman, S., R. Borland, M. Scollo, R. Brownson, A. Dominello and S. Woodward. "The Impact of Smoke-Free Workplaces on Declining Cigarette Consumption in Australia and the United States." *American Journal of Public Health*, 1999, 89(7) 1018-23.

Cutler, D. and E. Glaeser. "Social Interactions and Smoking." *NBER*, 2007, Working Paper number 13477.

de Bartolome, C.A.M., “Tax competition and the creation of redundant products,” *Canadian Journal of Economics,* 2007, 40, 1213-1236.

DeCicca, P., D. Kenkel, A. Mathios, Y-J Shin and J-Y Lim. "Youth smoking, cigarette prices and anti-smoking sentiment", *NBER* Working Paper, 2006, no. 12458.

Evans W, Farrelly M and E. Montgomery. "Do Workplace Smoking Bans Reduce Smoking?" *American Economic Review*, 1999, vol. 89(4), 728-747.

Fichtenberg, C., and S. Glantz. "Effect of smoke-free workplaces on smoking behaviour: Systematic Review." *British Medical Journal,* 2002, *325*(7357), 188.

Gagné, Lynda. "The Impact of Workplace Smoking Regulations on the Smoking Behaviour of Canadian Workers." 2008. *School of Public Administration, University of Victoria*.

Godtfredsen, N., E. Prescott, and M. Osler. "Effect of Smoking Reduction on Lung Cancer Risk", *Journal of the American Medical Association*, September 28, 2005, Vol 294, No. 12, p1505..

Gruber, J., and B. Koszegi. "Tax Incidence when Individuals are Time Inconsistent: The Case of Cigarette Taxes." 2004, *Journal of Public Economics*, vol. 88, 1959-87.

Health Canada. 2008. http://www.hc-sc.gc.ca/hl-vs/tobac-tabac/about-apropos/role/municip/bc_e.html

Hepburn, C. "Regulating by Prices, Quantities or Both: an Update and an Overview." 2006. *Oxford Review of Economic Policy*, 22(2), 226-247.

Moskowitz, J., Z. Lin, and E. Hudes. "The Impact of Workplace Smoking Ordinances in California on Smoking Cessation." *American Journal of Public Health*, 2000, 90(5), 757-761.

O'Donoghue, T. and Rabin, M. "Risky Behavior among Youths: Some Issues from Behavioral Economics." In J. Gruber (ed.), Risky Behavior Among Youths: An Economic Analysis, 2001, *University of Chicago Press*, Chicago.

Pogue, T. F. and L. G. Sgontz. "Taxing to Control Social Costs: The Case of Alcohol." *The American Economic Review* 1989, March, 75(1), 235-43.

Stern, N. The Stern Review on the Economics of Climate Change." Report produced for H.M. Government, 2006. Health Canada. 2008. http://www.hmtreasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

Weitzman, M. (1974): "Prices versus quantities." 1974. *Review of Economic Studies*, 41(4), 477-491.

ENDNOTES

1. In Canada the presence of the illegal market can easily be demonstrated by comparing data showing cigarette shipped to the different provinces (data available from Statistics Canada, 2007) with survey data indicating cigarettes smoked in each province (data available from CTUMS, 2007). In the US.... and in Europe....
2. See Footnote 2.
3. If c_1 and c_3 were increased to fully offset the fall in c_2, health would be unchanged but the variance would be increased, implying that the smoker would want to lower consumption.
4. Introducing a fixed cost of smoking would lead a ban to cause some smokers to quit (the critical value of α^i decreases.
5. We consider F to be exogenous and not a policy instrument.
6. The smoker is forward-looking in the sense that he recognizes that current smoking will affect his future health. However, because the model focuses on short-run addiction, the long-run addictive effect of current smoking on the individual's taste for future cigarettes is ignored.