An Economic Model of Youth Smoking:
Welfare and Tax Effects

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Abstract:

This paper develops a model of smoking choice in which rationality is bounded by limitations in intertemporal computational abilities. The model is applied to the youth decision to initiate smoking. Lifetime smoking paths of representative smokers are shown to demonstrate why youth smokers may experience a reduction in lifetime utility and come to regret their decision to smoke. It is suggested that public policy interventions that can raise the near term cost of smoking will be more effective than informational campaigns that emphasize future health costs.   However, youth taxes may need to be quite high to substantially reduce smoking rates among youths that have already begun to smoke. Also, youth taxes may not prevent future smoking as an adult, although it is likely to reduce smoking rates and lead to earlier quitting.

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1. Introduction

Use of tobacco is attributed to over 430,000 early deaths in the US each year making tobacco use the number one preventable health problem.   Each day, according to the American Lung Association, more than 4,800 adolescents (ages 11-17) will try their first cigarette. Among these, more than 2,000 will become regular smokers. Currently more than 4.5 million adolescents smoke. This amounts to 28% of US high school students and 11% of middle school students. It is estimated that if current smoking patterns persist, more than 6.4 million of today's teenagers will die prematurely from a smoking-related disease.[1] Adding to this concern is the fact that teen smoking rates were again on the rise during the 1990s.[2]

Concern about the potential health consequences of teen smoking are heightened by the fact that most adult smokers began smoking when they were teens, and most of those began before they were of legal smoking age.[3] Most teens are aware of the negative health consequences but many choose to smoke nonetheless. For many teens, they expect that smoking will be a temporary, rather than a lifetime activity. Only 5% of teens expect to be smoking within 5 years. In reality, about 75% of them are still smoking after 5 years.[4] Since cigarettes contain nicotine, an extremely addictive agent, quitting smoking proves to be very difficult for most, and impossible for some.   Thus, intervention to arrest smoking initiation among teens may have a considerable long-term positive impact on public health.

In recent years interventions have included campaigns to encourage merchants to check IDs before selling to potential minors coupled with fines for merchants caught selling to

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[1] American Lung Association Fact Sheet, Teenage Tobacco Use,
http://www.lungusa.org/tobacco/teenager_factsheet99.html
[2] See Gruber (2000).
[3] According to the National Population Health Survey of Canada, 1994, 86% of adult smokers began at age 19 or earlier, while 86% began age 17 or before. 16% of adult smokers began before age 14. See
http://www.cansim.com/Daily/English/980429/d980429.htm
[4] Gruber (2000).

underage smokers, bans on vending machines located in areas accessible to youths, and bans on cigarette advertising on the broadcast media. There has also been a major effort within elementary schools to educate children about the risks inherent in smoking and to promote strategies for avoidance. These policies are designed to reduce youth access to tobacco products and to provide sufficient knowledge to encourage youths to choose not to smoke.

However, some of these policies have been shown to be quite ineffective. As an example, the Hutchinson Smoking Prevention Project (HSPP) was a 15-year study conducted by the Fred Hutchinson Cancer Research Center and supported by the National Cancer Institute (NCI). The purpose of the study was to determine the long-term impact on youth smoking resulting from a school-based intervention from the third through 12th grade. The study showed that there was no impact from the intervention programs in reducing youth tobacco usage.[5]

These facts point to a need for further study of the smoking initiation process. There are several theories often mentioned when discussing the logic of teen smoking. First, many people believe that teens are short sighted; teens think only about the present and very little, if at all, about the future.   In other words, teens are myopic. They make a decision to smoke based only on the benefits they receive today and take no account of future consequences. If this were true, information about health consequences would have absolutely no effect upon teen smoking decisions.   Also, if true, one could argue that government intervention, such as taxation, to prevent teen smoking, would be justified since teens are making an "immature" decision by not taking into account the future health consequences.

A second theory assumes teens are immature and cannot process or evaluate information properly. In this case, it is not ignorance of the effects, per se, but limited life experiences

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[5] See National Cancer Institute, http://www.cancer.gov/newscenter/hutchqanda.

that results in an inability to properly balance the full costs and benefits associated with smoking.[6] Since the decisions made are not what a person with mature calculating abilities would choose, one can argue for government intervention on paternalistic grounds. Taxes or other restrictive policies could be designed to protect youths from their childish choices.

A third theory would suggest that teens do recognize the future negative consequences of current smoking but have unreasonably high discount rates.[7] In this case, despite possibly good information about future health effects, those highly discounted future losses are not large enough to overwhelm the short-term benefits from smoking. This theory is similar to the second since it is a problem of faulty calculating abilities derived mostly from the inexperience of youth that induces a choice to smoke.

A final theory would suggest that teens do recognize the future negative consequences of current smoking and have reasonable discount rates, however, they may discount future costs enormously because the health effects occur mainly at the end of life, which is very far away. Thus, their discount rate may be normal, yet due to the distance in time, future losses may not be large enough to overwhelm the short-term benefits from smoking. The latter two theories would accommodate the notion that information about future health effects may influence teen decisions about smoking, however it might be necessary to exaggerate those effects in order to have a discernable influence on behavior.

In this paper's approach to teen smoking initiation, which extends the analysis in Suranovic et.al., (1999), it is assumed that teens do make a determination about whether to smoke by weighing the perceived costs and benefits. However, unlike the rational choice and hyperbolic discounting models in the economics literature, [Becker-Murphy (1988),

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[6] See Herrnstein and Prelec (1992)
[7] See Becker-Mulligan (1997) for a discussion of variable discount rates.

Gruber-Koszegi (2002)] it is not assumed that teens plan a complete future course of smoking. Instead, it is assumed that teens choose whether to smoke on a period-by-period, day-by-day basis. I'll assume that teens are sophisticated enough to recognize the future health consequences of smoking and factor that into their decision each period. Teens will also be responsive to the withdrawal costs that arise if they cut back their consumption after having achieved a habitual rate of smoking. However, teens lack the sophistication of an intertemporal maximizing agent who would recognize that all future consumption choices may affect one's current choices, and vice versa. The motivation for this assumption is twofold. First, as argued in Suranovic, Goldfarb and Leonard (SGL,1999), the boundedly rational setup is a better description of the actual way individuals make decisions. Second, the model provides better intuitive explanations for many of the empirical observations involving cigarette consumption. The model also provides an alternative justification for government intervention. Government intervention corrects individual "mistakes" that arise from the inability to calculate and stick to an optimal lifetime consumption path.

1.1. The Initiation Process

The initial decision to smoke is likely to be considerably more complex than will be reflected in this model. As a first step, I will explain the initiation process. Afterwards I will indicate how the process will be modeled.

One thing to recognize about youth smoking is that very young youths are generally restricted from consuming cigarettes. Unlike most goods, youths do not have opportunities to sample cigarettes and thus will not know precisely how much utility a cigarette might provide. On the other hand, youths will recognize that smoking is an "adult" good and since youths often find value in acting adult, may imagine a positive utility in consumption even if

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cigarettes had never been sampled. In addition, youths may observe from social settings that smokers have certain qualities worth emulating, that is, smokers may seem "cool." This is an image that can be reinforced through popular cinema and advertising. Thus, sampling is not necessary for a youth to form a positive preference for cigarettes.

Youths also face another problem consuming cigarettes. In most cases, parents and guardians do not allow youth smoking in their presence. Since very young children experience virtually constant adult supervision, even if they had a desire to smoke, the consequences of smoking in the presence of adults would undoubtedly lead to severe reprimand and punishment.   Thus, for young children the cost of smoking (in the form of punishment) is very high and would likely overwhelm any perceived benefits.

However, as youths reach middle school ages, the amount of unsupervised time begins to rise. This provides periods of time during the day where the punishment cost of smoking may fall close to zero, (because you won't be seen). A likely scenario may be a middle-school age youth left home alone when there are cigarettes left in the house by an adult family member. A second common story is when kids walk home from school through an isolated area. If one has easy access to a cigarette, (perhaps one obtained surreptitiously at home) one youth may inspire a whole group to experiment. In this case, the common phenomenon of peer pressure may suddenly raise the perceived benefits of smoking in order to be accepted as cool by one's peers.

At this stage a youth may begin an experimentation stage. Cigarette consumption may occur only sporadically since unsupervised time and cigarette availability may also be somewhat random. During this time a youth has an opportunity to reach an informed opinion about the utility benefits of smoking. These benefits may arise partially from peer

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acceptance and partially from the physical effect of nicotine and cigarette smoking itself. This latter effect is more likely to be learned at this stage, but the former effect might also be solidified as a youth determines how important smoking is to remain a part of this peer group.[8]

In the model, the smoking initiation process is simplified by concentrating the experimentation and learning phase into an instantaneous shock to the youth's utility function at a young age. This shock makes it beneficial to smoke if no additional effects of smoking are considered. If smoking ensues, a stock of smoking capital will grow (reflecting habits or past history) that will in turn affect the utility through a reinforcement and tolerance effect. Reinforcement means that past smoking tends to raise the marginal utility of current smoking. Tolerance means that greater past smoking will lower the utility of any current smoking level. These two features imply that the youth's utility for cigarettes will change as a function of his past smoking history.

2. The Model

The model considers the decision process of an individual smoker. We imagine the costs and benefits of smoking arise in three distinct ways; as immediate benefits of consumption derived while smoking, as perceived future smoking-related health losses, and as withdrawal or quitting costs if consumption is cut back from one's habitual level.[9]

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[8] Survey studies have defined smokers as "experimental smokers" if one has smoked less than 100 cigarettes in their lifetime and "established smokers if one has smoked more than 100. See Ross, Chaloupka and Wakefield (2003) for a description of the smoking uptake process.
[9] The habitual level is defined as the level of smoking chosen in the previous period.

2.1. Current Benefits from Smoking.

Consumption of cigarettes generates benefits just as other consumption goods do, however, one's past usage, or stock of consumption will also affect the utility obtained. Two additional features of tobacco consumption, that distinguish it from normal goods, are reinforcement and tolerance. Tolerance refers to the reduced effectiveness of addictive drugs as usage increases; i.e., one gets less utility, or less of a "high," as past consumption cumulates. Reinforcement means that as past usage of the drug rises, the current marginal utility of consumption rises. Reinforcement and tolerance combine to induce an individual to crave a drug and wish to consume more of it.[10]

For simplicity, I adopt the quadratic utility function used in Becker-Murphy (1988) and Gruber-Koszegi (2002). The specific function is:

$$B_A(c, S_A) = \acute{a}_c c + \frac{1}{2}\acute{a}_{cc}c^2 + \acute{a}_{cs}cS_A + \acute{a}_s S_A + \frac{1}{2}\acute{a}_{ss}S_A{}^2 \tag{1}$$

Here, B_A refers to the current benefits of smoking at age A, c is the current period daily level of cigarette consumption, S_A is the accumulated past stock of cigarette consumption as of age A, while the αs are exogenous parameters such that α_C and α_{CS} are positive while α_{CC}, α_S, and α_{SS} are each negative.

Tolerance requires $\partial B(c, S_A)/\partial S_A < 0$. Thus, for the specific utility function assumed, we need:

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[10] This component of the utility function incorporates positive reinforcement as one aspect affecting the individual's choice. See Glautier (2004) for an overview of positive reinforcement modeling in the literature.

$$\frac{\partial B_A(c, S_A)}{\partial S_A} = á_{CS}c + á_S + á_{SS}S_A < 0 \qquad (2)$$

Reinforcement requires that $\partial B(c,S)/\partial c \partial S > 0$. The specific utility function assumed yields the following expression for the marginal utility of a cigarette:

$$\frac{\partial B_A(c, S_A)}{\partial c} = á_C + á_{CC}c + á_{CS}S_A \qquad (3)$$

It follows that $\partial B_A(c,S)/\partial c \partial S_A = \alpha_{CS} > 0,$ which incorporates the reinforcement effect.

2.2. Health Effects of Smoking.

I assume that individuals recognize the future health consequences of smoking and incorporate this explicitly into their decision-making process. In the Becker-Murphy and Gruber-Kosegi models, health consequences are implicitly incorporated through the tolerance effect and through an effect on future wealth. However, neither effect is explicitly placed at the end of life in these models, thus they do not capture an important element of these effects.[11]

Suranovic, Goldfarb and Leonard (SGL,1999) present several ways to model a perception of future health effects. The first method is to assume that each cigarette smoked reduces one's life expectancy by a fixed amount of time. For example, a recent study reported in the British Medical Journal indicates that every cigarette consumed reduces one's

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[11]   See Goldbaum (2001) for an explicit treatment of end-of-life health effects in a B-M type model.

life by eleven minutes.[12] An alternative approach is to assume that each cigarette raises the probability of early death in all future time periods. For computational efficiency reasons, I will adopt the first model since the results are quite similar under either assumption.

Consider a person who expects to live until an age defined by their life expectancy. Suppose every cigarette consumed reduces this person's life expectancy by a fixed amount of time. Individuals evaluate future losses by calculating the present discounted value of the expected reductions in length of life weighted by their expected utility in that period. The expected future health losses, L, can be written as,

$$L(c, S_A) = z \int_{75 - bS_A - bc}^{75 - bS_A} e^{-r(t-T)} dt \tag{4}$$

In this paper I'll begin with an individual approximately 15 years old. Here I'll assume a 15 year old expects to live to age 75.[13] Assuming every cigarette smoked reduces life expectancy by a fixed amount, a smoker's life expectancy at age A can be written as 75 - bS_A, where b is a parameter indicating the number of life expectancy years lost per cigarette and S_A is the stock of cigarettes consumed by age A. The appropriate value to use for "b" is the individual's expectation of loss of life, which may or may not equal the actual loss of life. Survey results by Viscusi (2001) in Spain show that people estimate that 20 years of smoking 20 cigarettes per day will lead to a 10.94 year reduction in life expectancy. Based on this we will assume that each cigarette causes a loss of 39 minutes of life, which is considerably

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[12]   Dr. Mary Shaw et.al. British Medical Journal 2000;320:53

[13]   US life tables from 2000 indicate that life expectancy for a white male 15 year old is about 60 years, for a black male it is 54.6 years while for females it is 65.2 years. See
http://www.cdc.gov/nchs/fastats/pdf/nvsr51_03t11.pdf

higher that the actual effect estimated to be between 7 and 11 minutes per cigarette.[14]   In the

expression, "bc" represents the additional loss of life expectancy that arises due to the

additional cigarettes, c, smoked at age A. z represents the per period expected utility value

attributed to one's end of life. The health losses, then, represent the additional losses of

utility that occur due to the additional cigarettes smoked this period, discounted at a rate of r,

from the perspective of time T.[15]

Health losses increase with smoking since each cigarette eliminates expected benefits in

the final moments of life. Losses rise at an increasing rate because each cigarette draws the

terminal date closer resulting in a higher discount factor being applied to the final minutes of

life.

2.3. Withdrawal Costs of Quitting

We assume that a smoker experiences withdrawal symptoms inducing utility losses

when reducing consumption below a previous habitual level. We define the habitual level, h,

as the previous year's daily smoking rate. These withdrawal symptoms represent a kind of

adjustment cost that occur only with reductions in consumption; the greater the reduction

below the habitual level, the greater the cost incurred. These well-documented costs may

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[14] It is important to recognize that we are merely trying to incorporate, in a mathematically useful way, a
person's *feeling* that smoking is harmful due to future health consequences. That feeling may not correlate very
well with actual, statistical, estimates of expected loss of life since most individuals do not have that info readily
at hand. Instead people process information heard in a variety of contexts into a negative feeling that weighs in
upon them.   Different individuals may have widely different inputs and may process that info differently,
leading to significantly variable feelings about the future health consequences of smoking. Actually, it would
be quite astounding if those feelings happened to correspond closely to the actual estimates.
[15] For most of the analysis I assume T = a. In other words, a person evaluates the health effects at the time one
makes the decision. However, when regret is considered later on, the period of evaluation T will not be the
same as the period in which a choice is made.

include anything from a loss of concentration to extreme irritability.[16] We use the following

functional form to represent an individual's withdrawal adjustment costs C:

$$C_A(c, S_A) = \begin{cases} \tilde{n} \sqrt{S_A (h^2 - c^2)} & \text{if} \quad h \geq c \\ \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

The function is chosen to have several important features. First, adjustment costs are

assumed to be zero for all consumption levels *above* the previous year's level of smoking, h,

which is treated as the habitual level.   As smoking is reduced below that habitual level h,

withdrawal costs rise. This implies that C is a decreasing function as c, the current level of

smoking, rises. Second, these adjustment costs are assumed to be a function of the past stock

of smoking, so that as the stock, S, rises, ceteris paribus, the adjustment cost of reducing

consumption also rises, albeit at a decreasing rate. The idea is that withdrawal effects are

likely to be larger the more habitual is the past usage of cigarettes. Lastly, ρ is a scale

parameter that affects the magnitude of these adjustment costs.

2.4. The Consumption Choice Problem

I assume that an individual at age A chooses a quantity of current cigarette

consumption and a quantity of a composite good "y" subject to a budget constraint so as to

maximize the present value of the previously defined current and expected net benefits. The

composite good generates utility only in the current period and has a utility function that is

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[16] Withdrawal effects incorporate negative reinforcement effects into the individual's choice problem. See
Eissenberg (2004) for an overview of negative reinforcement models in the literature.

additively separable from cigarette utility. Define $U_A(c, S_A) = B_A(c, S_A) - L_A(c, S_A) - C_A(c, S_A)$. The individual's problem then is,

$$\text{Max}_{c,y} \; W_A(c, S_A, y) = U_A(c, S_A) + \tilde{A}(y)$$
$$\text{s.t.} \qquad p_s\, c + p_y\, y = I_A \tag{6}$$

Assume that the individual makes an annual decision about how much to smoke. One year corresponds to one period in the model. Let c_t represent the average daily number of cigarettes consumed in period t. Assume the smoking stock depreciates at a rate of δ per year. The smoking stock at age A can now be written as

$$S_A = \int_{t=15}^{A} (1 - d)^{A-t} c_t \, dt \tag{7}$$

Rather than assuming a person learns about his true preferences through experimentation, I'll assume that a shock occurs at some date in the teen's life. The shock involves a sudden realization that there is positive utility associated with consumption of cigarettes. In essence, this represents a compression of the initial discovery and experimentation phase into an all-at-once event. I'll also assume that a teen's income, used to purchase cigarettes, is fixed. This abstracts from the reality highlighted in Emery et. al. (2001) that youths do not begin to buy cigarettes until they become regular smokers. I'll also ignore the fact that teen income may not be the appropriate budget constraint since they often rely on transfers from parents or obtain cigarettes freely from peers. Time paths of consumption are determined beginning at the time of the shock with a teen agent who has no
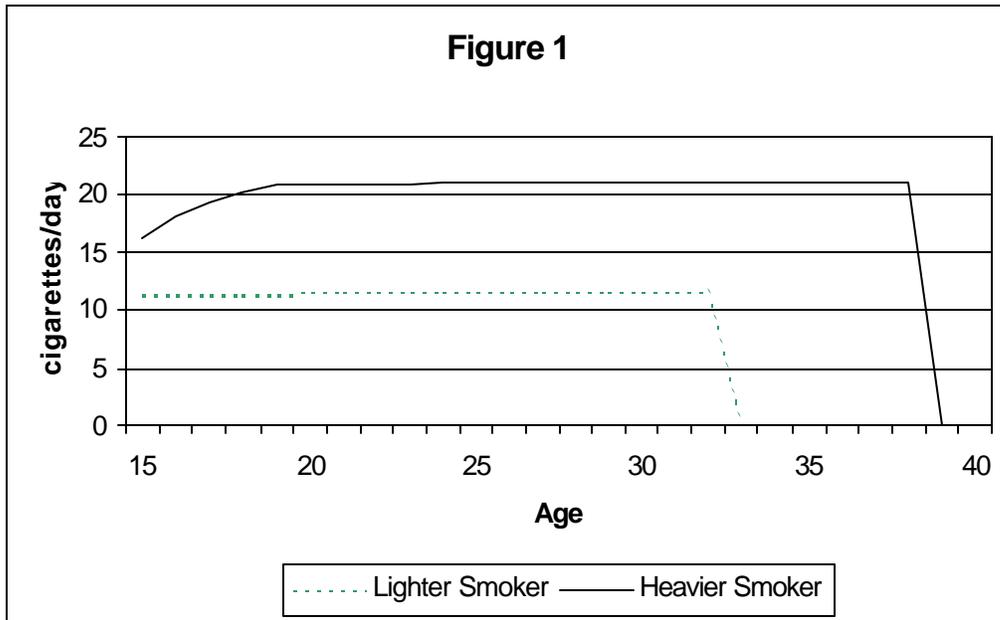
prior history of smoking. Optimal consumption for the teen in that year is then calculated.

For each successive year, determining the new consumption level involves the following: a)

the consumption stock is updated with the prior year's smoking rate; b) depreciation of the

smoking stock is calculated; c) the habitual smoking level is reset at the previous year's

smoking level; and d) re-optimization occurs. The individual **only** decides how much to

smoke in the current year and does not attempt to choose or predict future smoking choices.

It is in this sense that the teen's rationality is bounded. He makes a reasoned decision taking

some information about future mortality effects into account, but he does not attempt to

calculate the full future consequences of today's smoking.

3.   Simulation Results of the Model

3.1. Representative Smoking Time Paths

Consider a teen that experiences a shock to his utility function at age 15 in the form

of an instantaneous increase in the parameter α_c from 0 to a positive number. Two possible

time paths are shown in Figure 1. The light smoker time path assumes a smaller value for α_c.

The path for the heavy smoker, not only has a higher value for α_c, but also is assumed to

have a higher value for the reinforcement parameter, α_{cS}.[17]   For the light smoker,

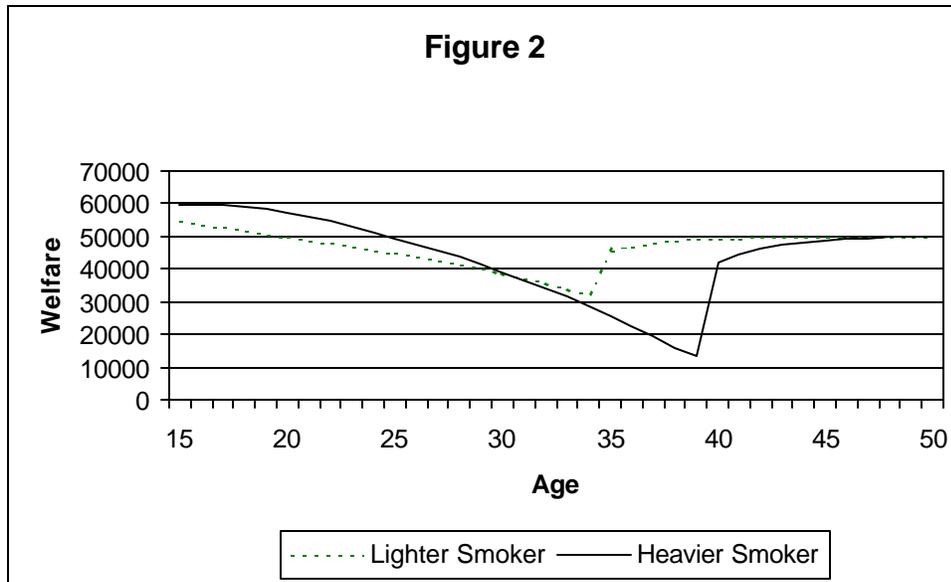consumption in the initial period is just over 10 cigarettes per day. The time path shows a

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[17] By adjusting the parameters it is possible to display many different types of smoking paths. If the benefits of smoking were very high, the cost of quitting high, and/or the perceived health costs of smoking very low, then a person would smoke for his entire life. If these parameters were skewed in the opposite direction, then a person might decide never to smoke. Understanding how these parameters affect the time path, provides an understanding of why people respond differently to similar stimuli (i.e., same prices, same advertising, etc.) Most economic studies of smoking attempt to fit their models to the statistical averages. Those approaches abstract from the richness of individual experiences that are captured in this model.

Figure 1

very moderate consumption increase to a plateau, attained through most of his smoking life.

At age 34, this smoker instantaneously quits smoking, cold-turkey, and refrains from

smoking forever after. For the heavier smoker, there is a more prominent increase in the rate

of smoking in early years. This arises due to the stronger reinforcement effect and is

consistent with teen smoking behavior.[18] The heavy smoker also reaches a plateau and also

quits cold-turkey. However, the heavier smoker quits more than five years later than the

lighter smoker; this despite the fact that both smokers are assumed to have the same

withdrawal, or quitting cost, function. Thus, the model is consistent with the observation

that heavier smokers have more difficulty, or at least wait longer to quit, than lighter

smokers.

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[18] A survey of California smokers shows that mean daily consumption for teen smokers was 12.5 cigarettes per day , while it increased to 15.5 cigarettes per day for daily smokers in their thirties. This is consistent with the reinforcement effect generating increased usage over time. It is also consistent with the fact that lighter smokers in this model will quit earlier in their lives, which also would lead to an increase in average daily consumption. See Pierce et.al. (1998).

The reason for the shape of time path can be seen more readily by plotting the smokers' utility levels across their smoking lives. This is shown in Figure 2. The base line

Figure 2

utility, i.e., utility attained if the individual refrains from smoking his entire life, is 50,000 utils per period. For both smokers, smoking raises utility in early teen years above that attained from abstinence. At about age 22 for the lighter smoker (27 for the heavy smoker), the welfare level dips below that which would have been attained had he never smoked. It is at this stage that a smoker is likely to regret his decision to start smoking and wish he were a nonsmoker. However, it is not optimal for the smoker to quit at this stage due to the presence of quitting costs. Quitting would be more painful than continuing to smoke. Thus the smoker will continue to consume for another 10 plus years, perhaps all the while feeling unhappy about it.[19] When cold-turkey quitting occurs at age 34 for the lighter smoker (age 39 for the heavy smoker), the smoker actually becomes even more miserable during the quitting year. However in the next and subsequent years utility rises rapidly since quitting costs are assumed to last for only one year and because smoking stock depreciation reduces

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[19] This is the justification for the "unhappy smoker" provided by Suranovic, Goldfarb and Leonard (1999).

the perceived future health consequences of past smoking.   Within about 5 years after

quitting for both smokers, welfare levels will revert to near the level had one never smoked.

3.2. *Measuring Lifetime Utility*

Measuring lifetime utility for this individual raises some important questions. It is

typical to evaluate welfare on a discounted basis from the viewpoint of the year in which the

analysis takes place. By its nature, discounting puts greater emphasis on the present over the

future.   However, when considering a person's life from a detached perspective, as could or

should be done for policy analysis, one should not put greater emphasis on any one year over

another. Similarly, and ideally, a person planning one's own life dispassionately, ought not

weight different periods differently. This is precisely what Jevons meant when he wrote, "to

secure a maximum benefit in life, all future events, all future pleasures or pains, should act

upon us with the same force as if they were present, allowance being made for their

uncertainty … time should have no influence."[20] Jevons conceded that to describe how

individuals actually do make intertemporal decisions, discounting must be applied.

However, the reality of discounting represents at best, a problem to be overcome, and at

worst a character flaw.

For these reasons, I will evaluate welfare effects ex post, using the undiscounted sum

of utility obtained by an individual during his lifetime. For contrast, I will also present the

discounted values of each lifetime utility stream for several different discount rates.

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[20] From Jevons (1872), quoted from Peart (2000) who also discusses similar points of view in the writings of
Fisher, Marshall and Pigou.

With this in mind, consider the lifetime welfare effects of the lighter smoker versus a nonsmoker in the above example. Assume the individual lives until age 75, his age15 life expectancy. The discounted values are evaluated from the perspective of age 15.[21]

Table 1 Lifetime Welfare (million utils)				
	Zero discount	5% discount	10% discount	20% discount
Non-smoker	3.05	.956	.499	.250
Light Smoker	2.93	.907	.483	.254
Heavy Smoker	2.83	.915	.514	.283

Table 1 shows that if we compare undiscounted utility between a non-smoker and a smoker, the non-smoker is best-off, while the lighter smoker is better-off than the heavy smoker. Evaluated this way, smoking harms the smoker and the more smoked, the worse-off a person will be. Despite this, because of the way in which the individual makes his period-by-period decision, in other words, due to his bounded rationality, he would still choose to smoke even though it will harm him over his lifetime. In contrast, if we assume the 15 year old has the information concerning his future utility stream under both smoking and non-smoking scenarios, he might evaluate these by comparing the present discounted values of future utility streams. At a low discount rate of 5%, non-smoking continues to dominate smoking for both the light and heavy smoker. At a 10% discount rate, the heavy smoker perceives a lifetime of smoking to be better than not smoking while the light smoker would still prefer not to smoke. At the much higher discount rate of 20%, both light and heavy smokers would

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[21] Note that utility is summed to age 75 for both non-smoker and smokers. This is because both representative smokers eventually quit. In time, the depreciation of the smoking stock implies that the life expectancy effect reverts back to that of a non-smoker. If the smoker smoked till the end of his life, then lifetime utility would be reduced by the early loss of life.

prefer the smoking path over the non-smoking path. It is possible to argue from this that a very high discount rate is needed to make an individual choose to be a smoker at young ages. However, this conclusion arises only if it is also assumed the individual is indeed maximizing the discounted value of the stream of lifetime utility. This is also why other authors argue that high discount rates are necessary to induce the kinds of smoking patterns that we see. However, one key feature of this approach is that high discount rates are not necessary to generate observed consumption patterns if the assumption about over-life optimization is dropped.[22]
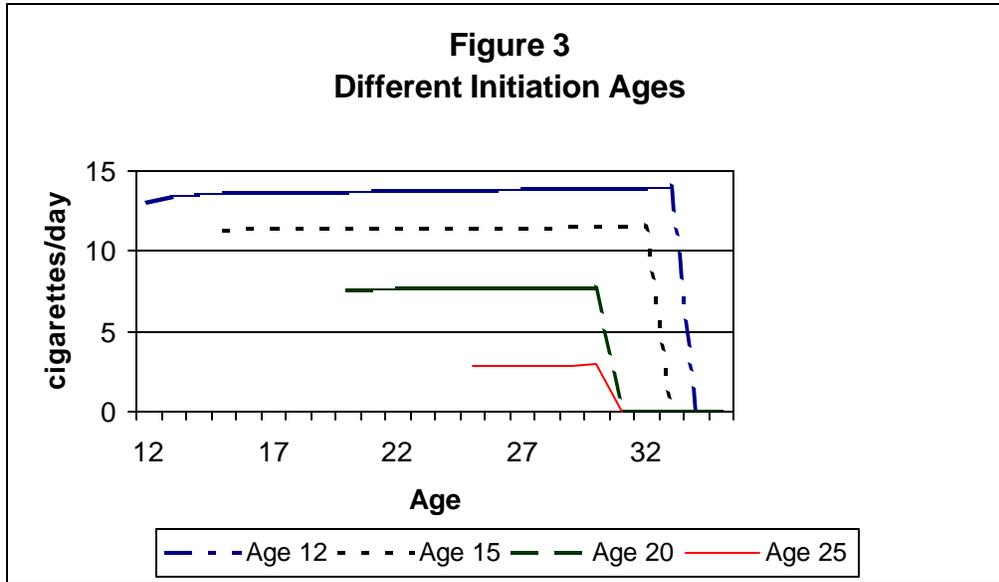
3.3. Smoking Initiation

The time path of smoking and the lifetime utility effects of smoking will depend in this model on the timing of smoking initiation. In the above example, smoking onset is at age 15, when a shock is presumed to have occurred. In Figure 3 below, time paths of smoking rates are shown for several different onset ages; age 12, 15, 20 and 25, in the case of the lighter smoker. The model shows that the earlier the onset of smoking among teens, the higher the daily rate of smoking and the longer smoking will continue before quitting occurs.[23] As shown, when smoking begins at age 12, the teen will plateau at 14 cigarettes per day, compared to 11 cigarettes for age 15 onset, 8 cigarettes at age 20 and 3 cigarettes at age 25. Clearly this would suggest that if youths can be prevented from smoking in the teen

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[22] Becker and Mulligan (1997) build a theory of endogenous time preference based in part on the observation that individuals have excessively high discount rates especially when young.

[23] This result is consistent with Gruber and Zinman (2001) and Auld (2003). Auld's data suggests that a youth who initiated smoking before age 14 is 5.5 times more likely to smoke later in adolescence than a youth that did not begin so early.

years, it will reduce the likelihood that they would ultimately begin. This occurs because the

health consequence of a cigarette become higher, as one becomes older, and since one is

Figure 3
Different Initiation Ages

nearer to the end of life where the effects are concentrated. Lifetime welfare for each of the

time paths shows that undiscounted utility rises the later is the date of smoking onset. This

offers support for the suggestion that today's teens would be better-off over their lifetimes if

smoking initiation is effectively delayed or prevented.

Another aspect of teen smoking not modeled here, but supporting this conclusion, is

the changing influence of peer pressure as one gets older. It is likely that the benefits of

smoking may fall as the teen moves into adulthood. Peer pressure, which is all-important in

teen years, may disappear entirely once a person reaches his twenties.   This could be

modeled as a falling η_c since the benefits of smoking would wane in time. This, coupled

with the rising health effects, would make it even less likely for an older youth to choose to

begin smoking. This also is consistent with the observed evidence that almost all smokers

began in their teen years.

3.4. Ex Post Regret

One piece of evidence sometimes cited to support cigarette regulation is the fact that smokers often wind up regretting their earlier decisions to smoke. Many smokers even regret smoking while they are smoking. This type of behavior truly confounds the rational choice approach to explaining addictive behavior. One paper that attacks this issue is by Orphanides and Zervos (1999). Their paper extends the Becker-Murphy rational choice model to include uncertainty about whether one is an "addictive type" or not. The addictive type suffers negative consequences from smoking in the future whereas a non-addictive type does not. At smoking onset, an individual does not know which type he is and thus makes a decision based on presumed probabilities. Later, his type is revealed to him. If he had chosen to smoke and ultimately learns that he is an addictive type, he regrets his initial decision.

However, this type of regret can only occur once a person begins to suffer negative consequences from smoking. In reality, many smokers regret their decision to begin smoking long before they experience such negative consequences.

This model here offers two distinct ways to model regret, neither of which is based on an ex post discovery of bad news. The first way is based on a simple comparison of the smoker's current utility, with the utility one would have attained had one never smoked. This is a simple comparison for a person to make since the thought experiment requires only the determination of how one would feel today if one had never smoked a cigarette, did not have an urge to smoke a cigarette, did not experience any withdrawal effect from smoking, and felt no concern about one's future health consequence from smoking. This is equivalent to asking, what if I receive no utility or disutility from cigarettes? Comparing that with a smoker's utility from smoking will generate regret whenever the utility effects of present

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smoking are negative. As shown in the above welfare plot in Figure 2, welfare will fall below the non-smoking, baseline level, for quite a few years before smoking cessation occurs. During this entire period a person would reasonably regret his decision to become a smoker. However, he cannot instantly erase the pent up stock effect of past smoking, therefore he cannot eliminate the painful withdrawal effects that would arise from cessation. Thus, he continues to smoke, and continues to regret it, until the cost of quitting is less than the cost of continuing.
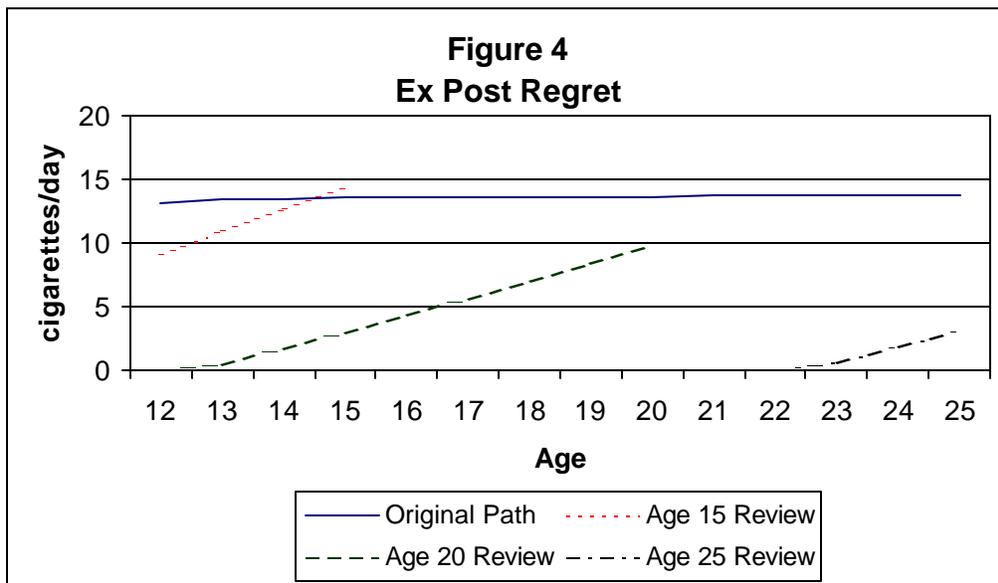
The second way a person might come to regret his past decisions is through a kind of ex post evaluation of past decisions. Suppose a person were to contemplate at the ripe old age of 20, whether he *should* have smoked back when he was a teenager. More specifically, suppose a person were to calculate the optimal level of age 15 smoking from the vantage point, or perspective, of a 20 year old. How would he perform such a calculation?

Just as we would expect a person to discount future utility, such as the future health consequences, in order to value it today, so we should expect that a hindsight evaluation would also discount the decisions of the past proportional to one's "distance" from them. For example, the peer pressure effects, and hence the benefits from smoking, are likely to be weighted much more highly by the teen at age 15, then it would be by the "mature" 20-year-old. The 20-year-old self will be less likely to think that such peer pressure will contribute as much to their sense of well-being. The 30- or 40-year-old self would probably think even less of the peer pressure effects.

Thus, a simple way to model this effect is with a hindsight discount factor. A 20 year old will discount age 19 decisions by one year and age 15 decisions by 5 years, etc. Although we do not have an explicit peer pressure effect, one can still consider such ex post

evaluations in the context of the model.   The results are shown in Figure 4 for the case of the

lighter smoker.

The figure shows that a 15 year old teen would prefer to have smoked about 40% less

at age 12 than he actually did.   Subsequent year smoking levels rise up to a similar level to

his current age 15 rates. For the 20 year old looking back, however, he would prefer to have

never started smoking at age 12.   His optimal smoking rate is considerably reduced for all

Figure 4
Ex Post Regret

years in hindsight including the current year. The reason he prefers to be smoking less

currently, at age 20, is because he wishes he had a lower past smoking stock, which would in

turn enable him to smoke less today. At age 25 the smoker wishes he had never smoked at

all during his teen years. He would still like to smoke a small amount presently, (perhaps

preferring to be an occasional smoker) but he clearly regrets his past smoking history. If the

evaluation is pushed up further to age 30, which is four years earlier than when he would quit

cold-turkey, the smoker's optimal time path is zero for all years. At this stage, the smoker

clearly regrets that he had ever begun to smoke.

Notice however, that regret, in this model, does not arise due to a lack of information. The individual has precisely the same info available at all dates. However, the information is processed differently, i.e., weighed differently, depending on one's vantage point in time.

3.5. Teen Smoking Intervention

As shown above, teens who choose to smoke may be reducing their welfare and are likely to regret their decisions at some future date. For these reasons it may make sense to intervene to prevent or reduce the initiation of smoking and the rate of smoking. The question then becomes, what methods are likely to be most successful in achieving that goal?

The model suggests that teens choose to smoke because the sudden and immediate benefits outweigh the perception of future health costs. Afterwards, teens become entrapped in smoking because the withdrawal costs rise up together with their growing habit. In order to change behavior, intervention that will change the parameters affecting teen decisions is required. Next we will discuss several alternatives and then focus attention on cigarette taxation.

3.6. Health Consequences

Since the Surgeon's General report on the dangers of smoking back in the 1960s, media attention has continued to raise public perception of the risks of smoking. School children are taught about the dangers of smoking in drug awareness programs in elementary schools. The effect of this increased awareness has contributed to a substantial decrease in the smoking rate in the US, down from 42% of adults in 1965 to 23% in 2001. This result is

consistent with our model since any increase in the perception of future health consequences will both prevent some individuals to start smoking and will lead smokers to quit earlier.

However, the effect of this governmental and media attention may have been to exaggerate the perception of negative health consequences.[24] This suggests that additional attention on the health consequences of smoking may not be likely to have a profound effect. This will especially be true for teens. Because teens already have good, perhaps even exaggerated, information about health consequences, and because teens discount future health effects much more than adults due to their distance in time, this would appear to be a very weak lever to affect teen decisions.

3.7 Quitting Difficulties

An alternative approach, complimentary to info about health effects, is to emphasize the withdrawal effects and the difficulties with quitting. If teens are aware that entrapment may occur, such that a few cigarettes today may lead to a lifetime of smoking, then they may be more likely to refrain.

In this model the effect of information about quitting is non-existent since teens are assumed to choose only how much to smoke today and do not make decisions about future smoking. In essence, information about quitting difficulties represent an encouragement to plan more intelligently; to recognize that today's smoking may affect tomorrow's decisions and to plan for one's future welfare. In this sense, it is like asking people to become more effective intertemporal optimizers and to overcome problems associated with bounded rationality.

While this may have a small effect on teens who are at the margin between smoking or not smoking, it is unlikely to have a major impact. First, teens who have never smoked

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[24] See Viscusi (1992) for evidence suggesting that smokers overestimate the true risk of smoking.

may have no first hand knowledge about withdrawal effects, (unless one witnesses a family member quitting). Second, teens will observe that many people do indeed quit smoking eventually. Furthermore, they will be aware that new effective quit-smoking techniques have become available suggesting reductions in the difficulty of quitting. Finally, teens will likely simplify the analysis in the following way. "Smoking is harmful, but if I quit eventually, there will be little to no long term harm." "Although quitting is difficult, it can't be that hard since many people have done it" "Thus, I'll simply do what I want to do for now, but to deflect criticism, I'll say that I 'plan' to quit sometime in the near future." Thus, the teen incorporates a plan for quitting is a very simplistic way and does not expend the mental energy needed to plan a lifetime path of consumption. For this simple reason, teens may underestimate their expected quit date.[25]

3.8. Resisting Peer Pressure

Programs for elementary school children recognize that children often are initiated to smoking by their siblings and friends. Thus, considerable emphasis is placed on teaching children to resist peer pressure. In terms of the model, this is an attempt to affect the $"_c$ parameter that affects the size of the benefits obtained through smoking. Peer pressure consists of encouragements to conform to the group and potential threats of banishment if one does not conform. Although a teen's initial perceived benefit from smoking may be low to non-existent, peers can affect the perception of benefits and costs and induce a person to begin smoking.

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[25] This issue is one of the motivations for the hyperbolic discounting models. The standard intertemporal rational choice model does not predict that people would change their mind, or plan inconsistently. The fact that teens say they will quit in five years and many do not, implies an inconsistency. Hyperbolic discounting models can explain this type of inconsistency in a dynamic model. However, the alternative explanation suggested here is simply that teens, by not attempting to formulate a sophisticated plan, make statements that appear to be inconsistent when in fact they are incomplete, i.e., no sophisticated calculation was made to derive them.

One potential problem with this approach is that it is, in effect, asking teens to disregard a component of their benefit function. To resist peer pressure means to ignore a very real component of the initial benefits of smoking. This would seem, prima facie, to be a very difficult thing for most people, and especially teens, to do.

3.9. Image of Smoking

Nevertheless, attempts to affect the μ_c parameter may be still be an effective method especially since it is a shock to this parameter that initiates smoking and it is the size of the parameter that affects how much a teen will smoke. Furthermore, reducing perceived benefits in the near term for teens should be more effective than raising perceived health costs at the end of life, due to the discounting of future health losses.

One effort in this regard is attempts to restrict cigarette advertising, especially advertising seemingly directed at teenagers. Well-known ads featuring the cartoon character Joe Camel had been widely criticized for their suspected appeal to teens or pre-teens. In 1997 RJ Reynolds agreed to eliminate all ads featuring the character. More recent efforts have focused on reducing the prevalence of smoking in major Hollywood motion pictures. A recent study suggests that over 50% of adolescent smoking initiation can be attributed to smoking in movies.[26]

Reducing the "glamour" in smoking is perhaps the most direct method to affect teen smoking initiation rates. This is different than attempts to counteract peer pressure since eliminating the glamour in smoking will reduce the μ_c of many teens simultaneously rather than the μ_c of just one individual teen. If many teens come to believe smoking is not glamorous, then peer pressure effects will be simultaneously reduced as well. However,

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[26] See Dalton, MA et.al., (2003).

policy effectiveness will also be influenced by whether public pressure or policy can induce the necessary changes in advertising, movies and other ve nues where smoking is glamorized.
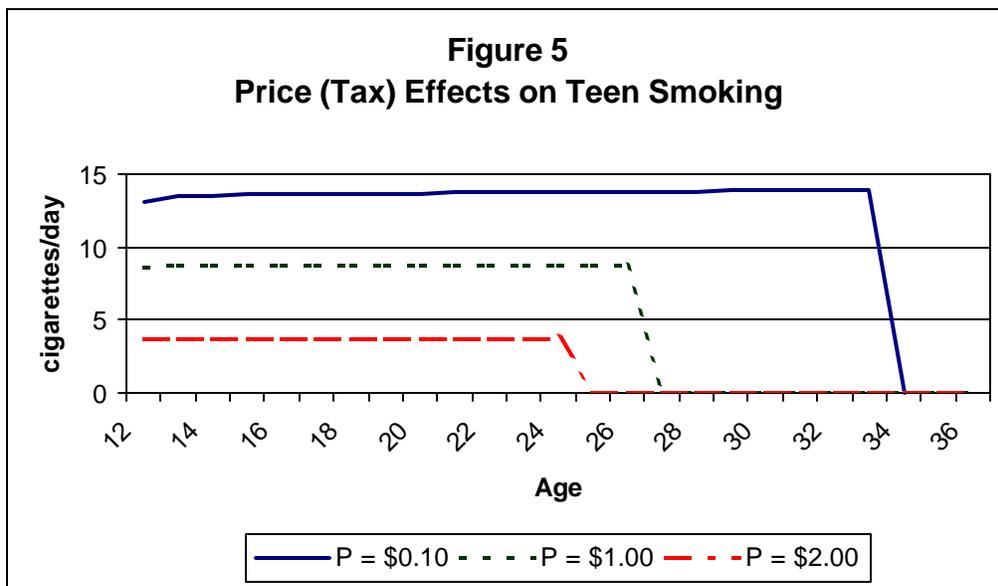
4. Effects of Cigarette Taxation

One policy suggested to help reduce or prevent teen smoking is higher taxes. There have been numerous empirical studies investigating the effects of taxes or higher prices on teen smoking. Ross and Chaloupka (2003) survey these studies and show that the results appear mixed. Some studies suggest some responsiveness to price. Some show more responsiveness for teens than for adult smokers. Other studies suggest there is little to no effect upon teen demand in response to price. However, more recent studies suggest that price increases can affect the process of initiation and uptake of cigarette smoking.[27]

Using this model we can investigate probable behavioral changes to higher cigarette taxes that strike at different stages of a teen's smoking history. The analysis will consider higher prices, assumed to come about as a result of an increase in a tax. First, I'll consider the effects of higher prices faced by the individual throughout his smoking history. In other words suppose the price of cigarettes were higher at the time the person reaches his teen years and that the prices remain at those high levels for the person's entire life. Afterwards I'll consider the effect of higher prices for a teenager who has already begun to smoke. Finally I'll consider the effects of a teen tax that raises prices only during a smoker's teen years.

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[27] See for example, Tauras and Chaloupka (1999), DiCicca et.al., (2002) and Emery et.al., (2001).

4.1. Lifetime Tax

First, consider the effects of a tax for the teen's entire life.   The effects of different

prices are shown for the heavier smoker in Figure 5. The original price is assumed to be 10

cents per cigarette, which means a price of $2.00 per pack. The solid line shows the

consumption path at this price. Smoking reaches a plateau at about 14 cigarettes per day and

cold-turkey quitting occurs at age 35 for this representative smoker.   A 10% price increase

has an almost imperceptible effect, so it is not displayed.   If the price rises tenfold to $1.00

per cigarette the smoking rate is cut almost in half and quitting ultimately occurs earlier at

age 28.[28] If the price is raised twenty-fold to $2.00 per cigarette, the smoking rate is reduced

Figure 5
Price (Tax) Effects on Teen Smoking

to about 4 per day and quitting occurs at age 26.   If the price is raised slightly higher the teen

could be induced to refrain entirely for his entire life.   Hence the model suggests first that

higher cigarette taxes are likely to reduce the quantity of cigarettes smoked over a smoker's

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[28] This corresponds to an elasticity of demand around -0.05 which is much lower than typical estimates. Measured elasticities are based on average effects across many different smoker types of many different ages. However, what is shown is simply the effect for one representative smoker. There has been no attempt to calibrate the model to mimic an average smoker since the point is more to demonstrate how variability in behavior can be explained.

lifetime and to induce an earlier quit date. This is consistent with the findings of Hamilton et. al (1997) who showed lower quit rates and higher initiation rates in Canada after a price increase occurred in the 1990s. Secondly, the results show that much higher cigarette taxes, which raise prices proportionally, could reduce or eliminate teen smoking but the levels of taxes might need to be very high.

The total welfare attained for each price is shown in Table 2. Also shown is the welfare level for a non-smoker. This corresponds to the case of a tax set sufficiently high to eliminate all smoking. The first column demonstrates that undiscounted welfare rises as the price/tax is increased. Thus, the greater the tax, the greater will be the lifetime utility of this representative smoker. If, in contrast, welfare is discounted at a low rate, say 5%, the price/tax increase would not raise welfare. The loss of welfare during the young, smoking, youth period would overwhelm the longer-term benefits. However if the discount rate were sufficiently high, such as at 15% shown in column 2, then welfare rises as the price/tax is increased.

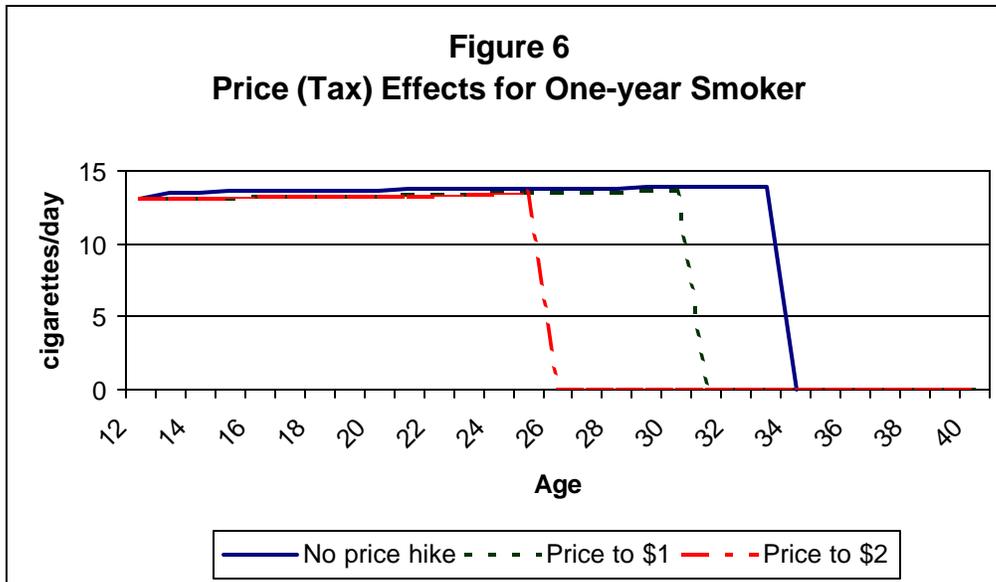|	Table 2		
	Welfare and Expenditure Effects of Taxes		
	Undiscounted Welfare	15% discounted Welfare	Average daily expenditures
Non-Smoker	3.20	.333	$0.00
Price = $2.00	3.17	.326	$7.46
Price = $1.00	3.14	.326	$8.72
Price = $0.10	3.02	.333	$1.37

Note also that daily expenditures rise dramatically for the continuing smoker as price/tax is raised despite the reduction in consumption. At the price of $2 per cigarette the reduction in consumption finally catches up with rising price and expenditure falls.[29]

On the other hand, this analysis treats teens and their consumption decisions as if they had their own income and made choices about how to allocate spending between cigarettes and other goods. Since early teens are dependent on their parents for most of their consumption, the effects of higher prices may not work as shown. Indeed, teens may be more sensitive to price changes than indicated especially if cigarettes make up a substantial amount of their disposable income.

4.2. Tax after smoking initiation

Next consider a tax on cigarettes that is implemented after a teen has already begun to smoke. Figure 6 depicts a base case smoking path for a smoker that begins at age 12 and faces no price change from the initial price of $0.10 per cigarette. The effect of a price increase is shown in two cases. The "price to $1" line shows the path for a smoker who begins at age 12 but experiences a 10-fold price increase one year later. Note that the significant price increase has almost no effect upon the smoker's consumption level. It will reduce it very slightly, but not even a discernable difference. The main effect of the price hike is to induce quitting to occur three years earlier.

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[29] For a heavier smoker undiscounted welfare can fall with the increase in the price/tax. This is due to the fact that a much larger share of income is spent on cigarette consumption and quitting occurs at a much later date, if at all. This suggests that the welfare effects will be influenced by the type of smoker an individual is.

Figure 6
Price (Tax) Effects for One-year Smoker

An even larger price hike to $2 is also shown. The price increase is also assumed to take place at the age of 13. A similar effect occurs, no significant decrease in smoking rate, but now a 5 year earlier quitting date.

The reason for this result is the presence of quitting costs. Once the teen has smoked for an entire year, he has built up a stock of consumption that in turn raises the withdrawal cost of quitting. Thus, despite the much higher prices, the teen will become trapped in his original decision.

If the price is raised much higher, earlier quitting will occur. Indeed, if the price is increased sufficiently, it is possible to show that immediate quitting would occur. However, the inelasticity of demand may be enormous in this instance.

4.3. Effect of a Teen Tax

One last policy change worth considering is the effect of a teen tax. It is commonly reported that the majority of smokers began their habit when they were teenagers. Furthermore, very few people begin to smoke once they reach their twenties. Thus, one
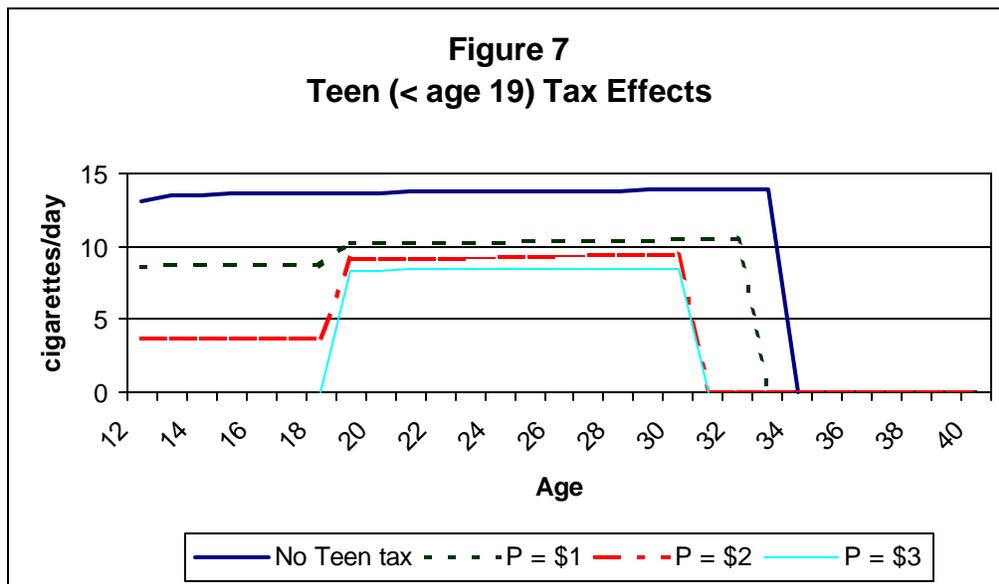
might conclude that if higher taxes and/or restrictions on teen smoking were implemented, this could prevent the onset of smoking and help people to lead smoke-free lives.

Possible restrictions include more stringent prohibitions for sales of cigarettes to minors, higher penalties for sales to minors, among other such policies. Also, since these types of regulations are targeted at teens, the objections related to paternalism on the part of the government are tempered slightly. These policies would be designed to affect underage teens, but leave the sales of cigarettes to adults largely unrestricted.

Although the implementation of these policies might affect the costs and benefits of smoking differently, I will consider, bravely, that the effect can be translated into a dollar equivalent effect resulting in an increase in price, i.e., a tax. In other words, suppose the effect of an increase in smoking restrictions on teens were equivalent to an increase in the price or cost of cigarettes. Furthermore I'll assume that since these prohibitions are presumed to affect teens and not adults, the effective price increase occurs only in the teen years.

Figure 7 displays the results for different levels of a teen tax. The original smoking path for a smoker who begins at age 12 is shown as the solid line. The other three lines show the effect of an increase in price that obtains only for ages 12-18. Afterwards it is assumed the price reverts to its original level. Notice several things. First, the effect of greater restrictions or taxes on teens is to reduce the level of smoking during the teen years. If the price is raised high enough, teen smoking may cease. However, the other, perhaps

surprising, result is that these restricted teens will raise their smoking levels up once they

Figure 7
Teen (< age 19) Tax Effects

become adults. This is true even for the smoker who refrained during his entire teen years.

This would suggest that successful prevention of teen smoking may not prevent adult

smoking. This result conflicts with the observation that very few individuals begin smoking

after their teen years. However, actual observations of twenty-something smoking initiation,

does not include individuals who began smoking as teens. This model depicts the effect for a

person who, before taxes, would have chosen to smoke, but who after teen taxes are set

chooses to refrain. Also, this result is consistent with Glied (2002) who concludes that,

"reducing smoking among teens through tax policy may not be sufficient to substantially

reduce smoking in adulthood."

However, despite the fact that adult smoking rises once the teen tax is removed, the

model predicts considerable reduction in smoking rates relative to the no teen tax base case.

Furthermore, quitting occurs at an earlier age for all who faced the teen tax.

The lifetime welfare level for each smoking path is shown in Table 3. We present

undiscounted welfare and welfare discounted at a 15% annual rate from the perspective of

the 12 year old. In terms of undiscounted welfare, the higher the teen tax, the greater is

lifetime welfare. If we consider discounted welfare then all tax plans are inferior to no tax

from the teen's perspective since he would place much weight on the missed smoking

opportunities foregone due to the higher taxes. If the discount rate were lower, say at 5%,

then the welfare effect follows the undiscounted pattern in that the higher the tax the better a

person would be.

Table 3 Lifetime Welfare with Teen Taxes (million utils)		
	Undiscounted	15% discount
No Tax Base Case	3.023	.333
Lower Tax	3.089	.328
Medium Tax	3.126	.326
Higher Tax	3.144	.330

One other factor not included in the model could make the teen tax even more

effective. If all or most teens refrained from smoking during the teen years then that might

affect the final size of the $''_c$ parameter. Recall that this affects the perceived benefits of

smoking. Those benefits might be much larger in the atmosphere of many other teens

smoking and the resultant peer pressures. However, if teens can avoid those pressures as

youths, these benefits might be much smaller once the teen is in his twenties. This would

imply that later initiation to smoking, once the teen tax is removed, might not occur.   In this

case the teen tax would prevent the onset of smoking and result in a definite increase in

lifetime welfare.

5. Conclusion

This paper has developed an economic model of smoking behavior and applied it to the issue of youth smoking initiation. The model assumes initiation begins with a shock to the smoking benefit function that makes smoking suddenly desirable. These benefits include both the peer pressure effects and the pleasures associated with nicotine consumption. A youth also recognizes the long-term negative health consequences by assuming each cigarette will reduce life expectancy. However, since this impact occurs late in life, it has only a small impact during teenage years. Once regular smoking begins, the smoking stock, or smoking history, rises to induce a reinforcement and tolerance effect typical of addictive goods. Cessation of smoking is also assumed to induce a withdrawal effect represented by a loss of utility.

The model assumes a youth makes a decision each year about how much to smoke to maximize net benefits. He or she weighs the benefits of smoking with the expected loss of life effect and the effects of potential withdrawal. The paper presents several timepaths of lifetime smoking histories that can arise under these assumptions. The paths demonstrate that once smoking begins, daily consumption may initially increase due to the reinforcement effect. Eventually a plateau level is reached and maintained throughout one's smoking years. Once the smoker reaches his 30s, smoking is suddenly ended cold-turkey. This occurs because eventually the loss-of-life effect outweighs the withdrawal effects. The timepaths clearly demonstrate that the kinds of smoking behavior typically observed can be explained under the assumptions of the model. Heterogeneity of parameter values among individuals would allow depiction of a wider range of smoking behaviors, including individuals who

would choose to smoke their entire lives and those who would choose to refrain their entire lives.

Calculation of welfare effects for a representative smoker shows that although smoking may raise welfare above non-smoking baseline for several teen years, during most of a youth's smoking history utility falls below baseline. Simple summation of undiscounted welfare is used to show that smoking can reduce over-life well-being for some smokers. The reason a person chooses something that makes him worse-off is due to a simple bounded rationality assumption. The teen simplifies the choice problem by choosing only for today, rather than planning a consistent over-life consumption pattern. It also shown why, under these assumptions, a teen may eventually regret his past decisions.

These implications are supportive of efforts for intervention, either governmental or otherwise, to help prevent smoking onset. This model suggests that interventions can reduce smoking and can be welfare improving for some smokers. In essence, interventions can prevent clear choice mistakes made because of difficulties in planning a consistent overlife consumption plan.

However, different types of intervention will have sometimes surprising results. For example, expanded education programs to inform youths about the dangers of smoking are unlikely to have much impact. First, because youths are reasonably well-informed already and are likely already incorporating that information into their choice problem. Second, because the health consequences are so far in the future, it would be necessary to exaggerate the effects considerably to have even a small impact on teen decisions.

Taxes (implemented as price increases) are also considered. It is shown that sufficiently high taxes could eliminate smoking and improve lifetime utility of potential

smokers. However, for the representative smokers shown, these taxes would need to be very high and would have to be maintained throughout one's lifetime. If taxes were raised only during teen years, as with a teen tax or with effective regulations, smoking could be reduced, but may not prevent a rebound of consumption once the restrictions are no longer binding. Finally, it is shown that higher taxes implemented after smoking has begun, may have little effect upon smoking levels due to the presence of withdrawal costs. However, such taxes would have the positive effect of bringing forward the date at which quitting occurs.

One weakness of this paper is that the analysis is done for a simulated consumption path only for several typical smokers. As such, it is impossible to infer what the effect of different tax rates might be on aggregate variables such as teen smoking rates, teen consumption levels, initiation rates or quit rates.

The key strength of this approach is that it allows us to identify several key parameters that may vary among the population and lead to the heterogeneous smoking decisions that are observed in the world. Most aggregate studies presume that smokers all conform to the model fitted to the societal averages and ignore the obvious heterogeneity that exists. With a more accurate model describing the individual decision-making process, it is easier to evaluate the effects of diverse policies that influence different aspects of the choice process.

It may also be possible to simulate the choices of the broader population. If several different smoker and non-smoker "types" could be characterized with different parameter combinations, an aggregate model calibrated with estimated demand elasticities could be constructed. It would then become possible to simulate the aggregate effects on smoking patterns due to tax increases.

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