Is Smoking a Fiscal Good?*

Shantanu Bagchi† James Feigenbaum‡

March 22, 2013

Abstract

Even though smokers incur higher health expenditures than nonsmokers of the same age, smokers have significantly higher mortality rates, so the expected lifetime health expenditure for a smoker is actually lower than for a nonsmoker. Because of this fact, some politicians and policy-makers have argued that society might actually be better off promoting smoking rather than discouraging it. We consider this argument in a general-equilibrium model where health expenditures are paid for by a single-payer health-care system financed by taxes. Because the percentage increase in the tax base is larger than the percentage increase in health-care expenditures, the elimination of smoking actually decreases the budget-balancing health-care tax rate.

JEL Classifications: E21, H51, I18

Keywords: general equilibrium, annuities, bequests, mortality risk, overlapping generations, smoking, health expenditures, single-payer health-care system, Social Security

*We would like to thank Frank Caliendo, Hui He, Kerk Phillips, Kent Smetters, and seminar participants at the BYU-USU Macro Workshop, the Midwest Macro Conference, and the Eastern Economic Association meetings for providing many helpful suggestions.

†Georgia Southern University; Statesboro, GA 30460-8152; sbagchi@georgiasouthern.edu

‡Utah State University; Logan, UT 84322-3565; J.Feigen@aggiemail.usu.edu

1 Introduction

Although physicians and the Surgeon General have convinced most of the American public that smoking is bad for us, the economic question of whether it is actually good policy to promote this message is not so clear-cut as the medical profession would have us believe. Because smokers have significantly higher mortality rates, even though a smoker incurs higher health expenditures than a nonsmoker of the same age, the expected lifetime health expenditure for a smoker is actually lower than for a nonsmoker (Barendregt et al., 1997). Because of this fact, some politicians and policy-makers have argued that society might actually be better off promoting smoking rather than discouraging it. Or at the very least the government should remain neutral on this issue rather than spending millions on anti-smoking efforts (Viscusi, 2009).

How governments deal with smoking is even more relevant internationally. At the same time that smoking rates have come down so sharply in the United States, they have increased substantially in the developing world.[1] Concerns about health-care costs may be used to justify a laissez-faire regime in the tobacco markets of these countries.

However, the argument that smoking is good for society naïvely considers only the effect of smoking on expenditures while ignoring the effect of smoking on national income. Nonsmokers cost more, but, because they live longer, they also contribute more to the economy. Proper consideration of this issue requires a model that fully characterizes how national income depends on the prevalence of smoking.

In this paper, we construct a general-equilibrium overlapping-generations model where households fall exogenously into two types: smokers and nonsmokers. These types differ only in their lifecycle profiles of mortality risk and health expenditures, and are identical in all other respects.[2] To motivate the governments interest in altering the fraction of smokers, we assume the government runs a single-payer health-care system financed by distortionary taxes on labor and capital. Politicians are primarily concerned with keeping the rates on these taxes low. We close the model by introducing a competitive firm and a Social Security program financed by a payroll tax on labor income.[3]

Since arguments against smoking interventions have largely arisen in the United States, we calibrate our model to match the present U.S. economy and examine the consequences of an experiment in which all smokers in the economy are replaced by nonsmokers. Politicians will judge smoking to be a fiscal good (or bad) if this experiment results in an increase (or decrease) in the budget-balancing tax rate needed to finance the health-care system. We also discuss the change in welfare of nonsmoking households, but this is unobservable. The public debate on health care has focused on its fiscal cost so this will be our focus too.[4]

In the simplest case of a health-care system where everyone pays the same premium, analogous to a poll tax, whether smoking is a fiscal good or bad is straightforward to judge. The percentage increase in health expenditures that comes from eliminating smoking is smaller than the percentage increase in population, so the per-person health care cost must fall after the experiment. Thus, smoking would be a fiscal bad in the scenario that most resembles an idealized world in which fully

[1]See, for example, http://www.wri.org/publication/content/8339 for smoking statistics in China, and Jha et al. (2008) for smoking statistics in India.

[2]In the baseline model we assume both types are equally productive, else it may appear we are biasing the analysis in favor of eliminating smokers. In Section 6 we consider what happens if smokers are less productive than nonsmokers.

[3]Eliminating smoking has a significant impact on the Social Security program since Social Security is an imperfect annuity under which the benefits to nonsmokers will be more costly than the benefits to smokers (Sheshinski, 2008).

[4]There is no simple way to compare the welfare of smoking and nonsmoking households, and it is not meaningful to ask about the welfare of households that do not exist after the experiment.

privatized insurance pays for all health care.

Most developed countries are actually closer to the opposite extreme in which the government pays for health care. The United States is in the middle of these two extremes, though its health-care system seems more likely to move in the direction of greater public financing. If labor and capital income are taxed at the same flat rate to finance health care, then the pertinent tax base is Net Domestic Product (NDP). In this case, smoking is a fiscal good only if the percentage increase in NDP is smaller than the percentage increase in health expenditures that comes from eliminating smoking. However, our model predicts that the opposite is actually true: the percentage increase in NDP from the elimination of smoking is, in fact, larger than the percentage increase in health-care expenditures. Consequently, we find that smoking is not a fiscal good when health care is financed through distortionary taxes.[5]

We also find that this result is quite robust. We calibrate the baseline model with an alternative set of parameter values, introduce productivity differentials between the nonsmokers and smokers, allow Social Security benefits to depend on work-life income, and finally allow the labor income tax to be progressive. In every single case, the budget-balancing health-care tax rate falls with the elimination of smoking.

The critical point of this paper is that smoking has a huge effect on national income. In our baseline analysis we consider the impact of changes in labor supply and the capital stock on factor prices. However, smoking is a fiscal bad even if we ignore the factor price changes. Indeed, for an open economy version of the model where factor prices are held fixed at their initial equilibrium values, elimination of smoking causes an even larger decrease in the tax rate needed to finance health care. In general equilibrium, eliminating smoking increases the capital stock, which by reducing the interest rate causes a negative feedback on the increase in the capital stock. This negative feedback is absent in an open economy, so the capital stock increases even more and the budget-balancing tax rate falls even further.

The one factor essential to our finding that smoking is a fiscal bad is that we consider the effect of smoking on both capital and labor. It is obvious that smoking must reduce the labor supply since it reduces the population, but that in itself does not have a large enough impact on NDP to make smoking a fiscal bad. What drives our result is that, in addition to working more, nonsmokers save more than smokers. Studying the effect of smoking on saving requires the full lifecycle model that we explore here.

When we examine the welfare effects of eliminating smoking, we find that this crucially depends on how the Social Security program changes in response to the resulting decrease in the worker-to-retiree ratio. If the payroll tax rate is held fixed and benefits from Social Security are cut after smoking is eliminated, the lifetime utility of nonsmokers typically moves, as one would expect, in the opposite direction from the budget-balancing health-care tax rate. If, on the other hand, the benefits are held fixed and the payroll tax rate is raised to balance the Social Security budget with the larger number of beneficiaries, nonsmoking households are worse off even when the health-expenditure financing tax rate falls.

Is it realistic to suppose that smoking rates might be reduced further from their current levels in the U.S.? Figure 1 shows that, since reaching a peak during the mid 1960's, annual per capita cigarette consumption by adults has steadily declined. A similar pattern is evident in Figure 2,

[5]We are actually underestimating the fiscal benefits of eliminating smoking since we do not account for externalities such as second-hand smoke or the lower propensity for fires. On the other hand, since we do not model the process by which smokers become nonsmokers (or vice versa), we do not consider here the cost of smoking interventions. We also do not account for lost excise tax revenue. However, the total of excise tax revenue accounts for a tenth of a percentage point of GDP (http://www.taxpolicycenter.org/taxfacts). This is an order of magnitude smaller than the changes in tax revenue that we consider here.

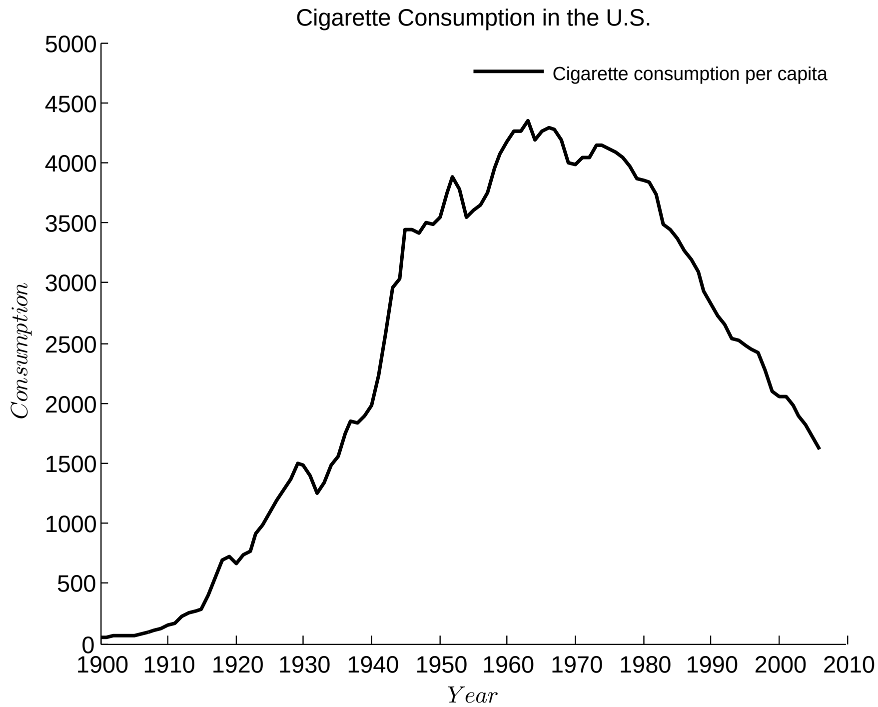

Figure 1: Cigarette consumption per capita in the U.S. for adults (≥ 18) from 1900-2006. Source: 2007 Tobacco Outlook report published by the Economic Research Service of the United States Department of Agriculture (USDA).

which reports data on the percentage of adults who are current cigarette smokers in the National Health Interview Survey, 1965-2010, published by the Center for Disease Control and Prevention (CDC). The fraction of adults who smoke has declined from above 40% in the 1960's to roughly 20% in 2010. Evidence that anti-smoking policies, such as bans on smoking in public places, taxes on cigarettes, and hazard warning labels, reduce smoking by adults is mixed.[6] However, the evidence of the effect on anti-smoking policies on teenage smoking behavior is more promising.[7] In particular, studies such as Levy et al. (2000) and Auld (2005) demonstrate that if individuals do not begin to smoke by their early 20s then they are unlikely to become habitual smokers. Without any further intervention by the government, it seems likely that, as fewer children are exposed to smoking on a regular basis, fewer children will take up smoking. Given the failure of the government to wipe out illicit drug use, it is doubtful that we could ever completely eliminate smoking. However, we can expect the rate of smoking to dwindle until it is comparable to rates of consumption for illicit drugs. With the exception of marijuana, for which the deleterious effects remain under dispute, most illicit drugs are used by less than 1% of the population.[8] Thus it is reasonable to suppose that the rate of smoking will eventually fall from the current 20% to near 0%.

Because of the projected insolvency of Medicare and insufficient coverage of private health insurance in the United States, the literature incorporating health care into macro models has recently exploded. This paper differs from the rest of the literature in that we focus on a specific condition, i.e. smoking, that is widespread enough for extensive data to have been collected regarding its

[6] See, for example, Anger et al. (2011), Buddelmeyer and Wilkins (2005), Bishop and Yoo (1985), DeCicca et al. (2008), and Thrasher et al. (2007).

[7] See, for example, Pentz et al. (1989), Wakefield et al. (2003), Farkas et al. (2000), and Lewit et al. (1997).

[8] The 2006 National Survey on Drug Use and Health.

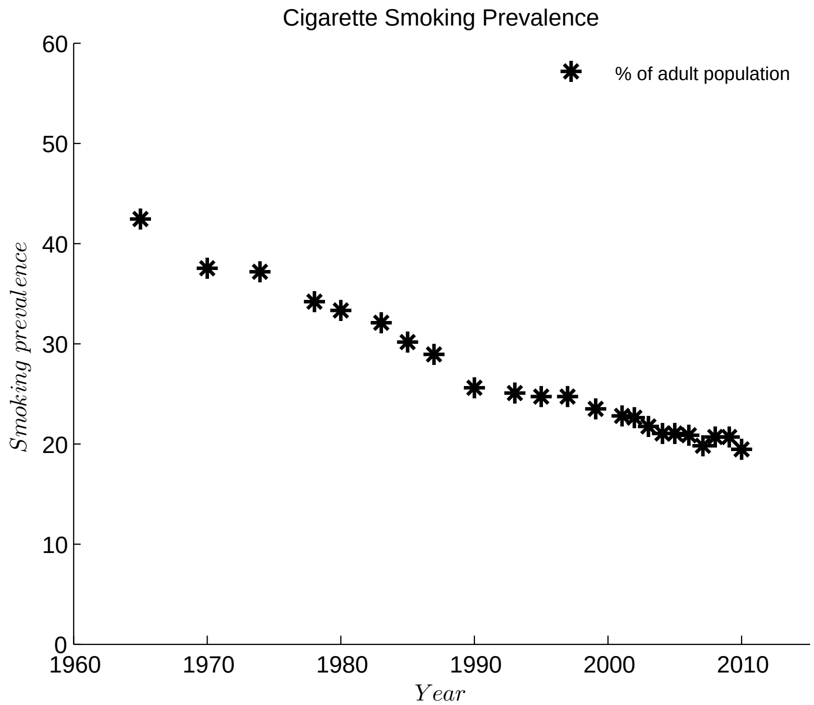

Figure 2: Percentage of U.S. adults (≥ 18) that currently smoke.

effects on mortality and health-care expenditures.[9] The literature is also split on whether to model the health-insurance system as a single-payer or multi-payer system. We focus on the single-payer case because the argument that smoking can be a fiscal good depends on the payments from smokers and nonsmokers getting mixed together into one fund that pays for everyone's health care. If smokers only pay for smoker's health care, and nonsmokers only pay for nonsmokers' health care, then smokers will bear all the cost of their smoking and nonsmokers will bear all the cost of their not smoking. Assuming a single-payer system also simplifies the problem since all health risk is borne by the government and has no effect on the household problem.[10] Moreover, we can disregard the adverse-selection problem that would arise if we modeled how the price of insurance is determined in markets where individuals are free to choose whether or not to buy health insurance.[11] We do not here consider in and of themselves the macroeconomic costs (He, 2010) or benefits (Huang and Huffman, 2010) of the distortionary taxes used to finance the single-payer health-care system.

The rest of the paper is organized as follows. In Section 2 we discuss in further detail the health expenditures and life expectancy data in Barendregt et al. (1997). We detail the model in Section 3, and the calibration procedure in Section 4. The results from our baseline model are reported in Section 5. We also do robustness checks with regard to the fiscal structure of the government in

[9] Papers that have studied the unconditional lifecycle pattern of health-care expenditures include De Nardi et al. (2009), Domeij and Johannesson (2006), and Halliday et al. (2009).

[10] He (2010) has shown there can be a significant moral hazard problem in a single-payer health care system if the choice of health-care accumulation is endogenized. On the other hand, Jung and Tran (2010) argue that the risk-pooling benefits of a medical voucher plan financed by distortionary taxes outweigh the costs of the tax distortions. Other papers that have considered a single-payer system include French and Jones (2011), Kopecky and Koreshkova (2009), and Zhao (2011).

[11] For examples of macroeconomic models with a multi-payer health-care system, see Attanasio et al. (2010) and Jeske and Kitao (2009).

Section 6. We discusses the welfare consequences of our experiment in Section 7, and we conclude in Section 8.

2 Smoking Status, Health Expenditures, and Life Expectancy

We take the study by Barendregt et al. (1997) as our starting point for examining how health expenditures and mortality rates depend on smoking status. Barendregt et al. (1997) look at the incidence, prevalence, and mortality associated with the following five major categories of disease - heart disease, stroke, lung cancer, a heterogeneous group of other cancers, and Chronic Obstructive Pulmonary Disease (COPD) - in the Netherlands. Using data on the differences in the frequency of these diseases between nonsmokers and smokers, along with the prevalence of smoking in the population, and the age- and sex-specific incidence of smoking-related diseases in a mixed population of nonsmokers and smokers, they estimate the incidence of these diseases by smoking status. Finally, these estimates are used to generate life tables for nonsmokers and smokers. Not surprisingly, they find that more people remain alive in the life table for nonsmokers than in the table for smokers, particularly in the older age groups.

Health expenditures in Barendregt et al. (1997) were obtained from studies on the allocation of the total costs for health-care in the Netherlands in 1988 by categories of age, sex, and disease. Using the Dutch population in 1988 along with the prevalence rates of the above mentioned smoking-related diseases among nonsmokers and smokers, they estimate the costs per case of disease according to age and sex. Using these costs per case along with the prevalence rates of these diseases among nonsmokers and smokers, they calculate health expenditures by smoking status. They find that health expenditures for smokers at a given age are as much as 40% higher than for nonsmokers (see the top panel in Figure 3). However, even though expenditures for smokers are higher, conditional on survival, the fact that their survivorship declines much more rapidly after age 70 leads to the result that nonsmokers cost more over the lifecycle (see the bottom panel in Figure 3). Consequently, the expected health-care costs in a population without smokers are over 5% higher than those in a mixed population. This finding is the basis of the argument that if a substantial portion of health-care expenditures are financed by public taxes, then smoking ought to be a fiscal good. However, this argument ignores the effect of smoking on the tax base that finances the health-care expenditures. In what follows, we consider this argument in the context of a calibrated general equilibrium model where the tax base is endogenous.

3 The Model

We construct an overlapping-generations model in which there are two types of households: nonsmokers, denoted by a subscript N, and smokers, denoted by a subscript S. At each instant t, a new cohort of unit measure is born. The fraction of these new agents that are of type i is f_i, where $f_N + f_S = 1$. Agents live to a maximum age T, and $Q_i(s)$ is the probability that a worker of type i survives to age s. The total population

$$P = \sum_{s=0}^{T} [f_N Q_N(s) + f_S Q_S(s)] \tag{1}$$

is constant.

We use the notation that a lifecycle variable $x_i(t + s, t)$ represents the value of x at age s for an agent of type i who is born at time t. An agent of type i born at time t will choose a lifecycle

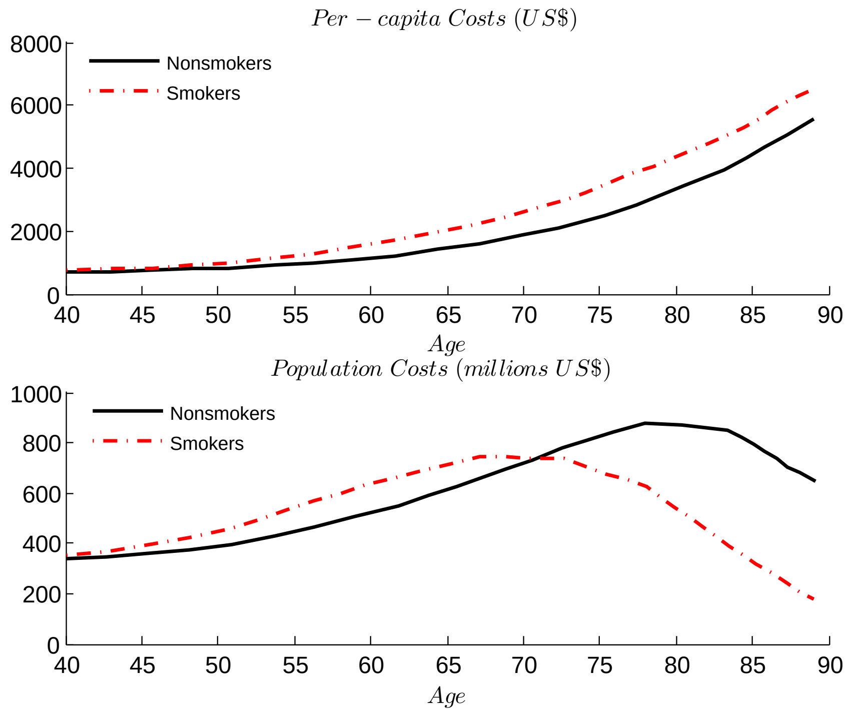

Figure 3: Health expenditures per capita and at the population level in Barendregt et al. (1997).

profile of consumption and leisure to maximize expected utility

$$\sum_{s=0}^{T} Q_i(s)\beta^s u(c_i(t+s,t)^\eta l_i(t+s,t)^{1-\eta};\gamma), \tag{2}$$

where $\beta > 0$ is the discount factor, $\eta \in [0,1]$ is the share of consumption in period utility, and $u(x;\gamma)$ is the CRRA utility function with risk aversion $\gamma > 0$:

$$u(x;\gamma) = \begin{cases} \ln x & \gamma = 1 \\ \frac{1}{1-\gamma}x^{1-\gamma} & \gamma \neq 1 \end{cases}. \tag{3}$$

A type i worker at age s has productivity $e_i(s)$, and therefore (gross) labor income $w(t)e_i(s)(1-l_i(t,t-s))$.[12] Labor income y is taxed at the rate $\tau_y(1+\rho y)$, where ρ is the degree of progressivity.[13] For ages $s > T_r$, workers also receive a Social Security benefit $b(t+s)$.[14] We also make the simplest assumption that workers start receiving benefits at age T_r regardless of when they stop working, and labor income is taxed to pay for this benefit at the same rate τ_{SS} both before and after age T_r.

Annuities markets do not exist in our model. Following Bullard and Feigenbaum (2007), we assume that the total wealth left behind by deceased households at any given point of time is spread uniformly across the surviving population at that time, resulting in an inheritance $B(t)$ at date t. Households accrue wealth by investing in capital $k_i(t+s,t)$, which earns the net interest rate r. The return on capital is taxed at the rate τ_k.

[12] For most of the paper, we assume $e_N(s) = e_S(s)$, but we relax that assumption in Section 6.1.

[13] This will be assumed to be equal to 0 except in Section 6.2.

[14] In the baseline specification, we assume that the Social Security benefit is unrelated to work-life income. However, we relax this assumption also in Section 6.1, where we entertain a concave benefit-earnings rule.

Thus a household of type i born at time t will solve the problem

$$\max \sum_{s=0}^{T} Q_i(s)\beta^s u(c_i(t+s,t)^\eta l_i(t+s,t)^{1-\eta};\gamma) \tag{4}$$

subject to

$$\begin{aligned} k_i(t+s+1,t) &= (1-\tau_{SS}-\tau_y(w(t+s)e_i(s)(1-l_i(t+s,t)))w(t+s)(1-l_i(t+s,t))e(s) \\ &+[1+(1-\tau_k)r]k_i(t+s,t)+B(t+s)-c_i(t+s,t)+\Theta(s-T_r)b(t+s), \end{aligned} \tag{5}$$

$$0 \le l_i(t+s,t) \le 1, \tag{6}$$

$$k_i(t,t) = k_i(t+T+1,t) = 0, \tag{7}$$

where

$$\Theta(x) = \begin{cases} 1 & x > 0 \\ 0 & x \le 0 \end{cases} \tag{8}$$

is a step function. Equation (6) is the constraint on the share of leisure in period time endowment, and (7) are the boundary conditions on the asset demand profile.

The economy is endowed with a production sector governed by the Cobb-Douglas production function

$$Y(t) = K(t)^\alpha(\exp(gt)L)^{1-\alpha} \tag{9}$$

at time t, where $K(t)$ is the capital stock at t, which depreciates at the rate $\delta > 0$, L is the supply of labor, and g is the growth rate of labor-augmenting technology. Firms behave competitively, and we assume that the economy is on a balanced growth path so factor prices are given by

$$w(t) = (1-\alpha)\left(\frac{K(0)}{L}\right)^\alpha \exp(gt) \tag{10}$$

$$r = \alpha\left(\frac{K(0)}{L}\right)^{\alpha-1} - \delta. \tag{11}$$

In equilibrium, we must have

$$K(t) = \sum_{s=0}^{T} [f_N Q_N(s) k_N(t,t-s) + f_S Q_S(s) k_S(t,t-s)] \tag{12}$$

and

$$L = \sum_{s=0}^{T} \left[f_N Q_N(s)(1-l_N(t,t-s))e_N(s) + f_S Q_S(s)(1-l_S(t,t-s))e_S(s)\right]. \tag{13}$$

Let $h_i(t,t-s) = h_i(t+s,t)(1+g)^{-s}$ be the average health expenditure of an agent of type i at time t and age s. Health expenses are paid for by a single-payer insurance plan run by the government. The total health expenditures at time t are

$$H(t) = \sum_{s=0}^{T}[f_N Q_N(s) h_N(t,t-s) + f_S Q_S(s) h_S(t,t-s)]. \tag{14}$$

These expenditures are financed by taxes on capital and labor income, collected at rates τ_y and τ_k respectively. The government must balance the budgets of both Social Security and the health-insurance program separately. The former constraint implies that

$$b(t) = \frac{\tau_{SS} w(t) L}{\sum_{s=T_r}^{T}[f_N Q_N(s) + f_S Q_S(s)]}. \tag{15}$$

The health-expenditure budget constraint is

$$\begin{aligned} H(t) \quad &= \quad \tau_y w(t) \sum_{s=0}^{T} [f_N Q_N(s)(1+\rho w(t) e_N(s)(1-l_N(t,t-s))(1-l_N(t,t-s))e_N(s) \\ &\quad + f_S Q_S(s)(1+\rho w(t) e_S(s)(1-l_S(t,t-s))(1-l_S(t,t-s))e_S(s)] + \tau_k r K(t). \end{aligned} \quad (16)$$

In the special case where $\rho = 0$, this simplifies to

$$H(t) = \tau_y w(t) L + \tau_k r K(t). \quad (17)$$

Finally, the bequest-balance equation is

$$B(t)P = [1+(1-\tau_k)r] \sum_{s=0}^{T} [f_N(Q_N(s)-Q_N(s+1))k_N(t,t-s-1)+f_S(Q_S(s)-Q_S(s+1))k_S(t,t-s-1)], \quad (18)$$

where the right-hand side is the after-return and after-tax value of bequeathed assets.

With this specification, a balanced-growth equilibrium at time t consists of lifecycle profiles $c_i(t+s,t)$, $k_i(t+s,t)$, and $l_i(t+s,t)$; a net return on capital r and wage $w(t)$; a bequest $B(t)$; a Social Security benefit $b(t)$; and taxes τ_y, τ_k, and τ_{SS} such that (i) $c_i(t+s,t) = (1+g)^s c_i(t,t-s)$, $k_i(t+s,t) = (1+g)^s k_i(t,t-s)$, $B(t+s) = (1+g)^s B(t)$, $b(t+s) = (1+g)^s b(t)$, and $w(t+s) = (1+g)^s w(t)$; (ii) the profiles $c_i(t+s,t)$, $k_i(t+s,t)$, and $l_i(t+s,t)$ solve the households' problem given the factor prices, taxes, the Social Security benefit annuity, and the bequest; (ii) the factor prices $w(t)$ and r satisfy (10)-(13) given $k_i(t+s,s)$ and $l_i(t+s,t)$; (iii) the taxes τ_y, τ_k, and τ_{SS}, and the Social Security benefit annuity $b(t)$ satisfy the government's budget constraints (15)-(17); and the bequest $B(t)$ satisfies the bequest-balance condition (18). See Appendix A for an outline of how to solve the model.

4 Calibration Procedure

We treat households as though they are born at actual age 25 and live to a maximum age of 100, so $T = 75$. Households earn Social Security benefits after actual age 65, which implies $T_r = 40$.

Health expenditures for a household of type i were obtained by fitting a fourth-order polynomial to the data from Barendregt et al. (1997). Let

$$h_i(t+s,t) = n_h \widetilde{h}_i(s)(1+g)^{t+s}, \quad (19)$$

where $\widetilde{h}_i(s)$ is time-0 health expenditures for a household of type i and age s, measured in dollars, and n_h is a normalization factor chosen to match $H/Y = 0.15$. The fitted health expenditures per capita are plotted for both types of households in Fig. 4. Not surprisingly, since smoking is bad for one's health, we get $\widetilde{h}_S(s) \geq \widetilde{h}_N(s)$ for all ages. Survivor probabilities for the two types of households were obtained from Rogers and Powell-Griner (1991), who further disaggregate data between light and heavy smokers. We average the probabilities for these two subtypes of smokers to obtain the probability that we use for smokers. Both series of probabilities were then fit to a sixth-order polynomial (which must be extrapolated for actual ages above 75). We normalize $Q_i(0) = 1$ for $i = N, S$. The resulting survivor functions for both types of households are plotted in Fig. 5. For comparison, we also include the survivor probabilities used for the representative agent in Feigenbaum (2008), which line up closely with the nonsmoker survivor probabilities. As one would expect, $Q_S(s) \leq Q_N(s)$ for all ages, since nonsmokers typically do live longer than smokers.

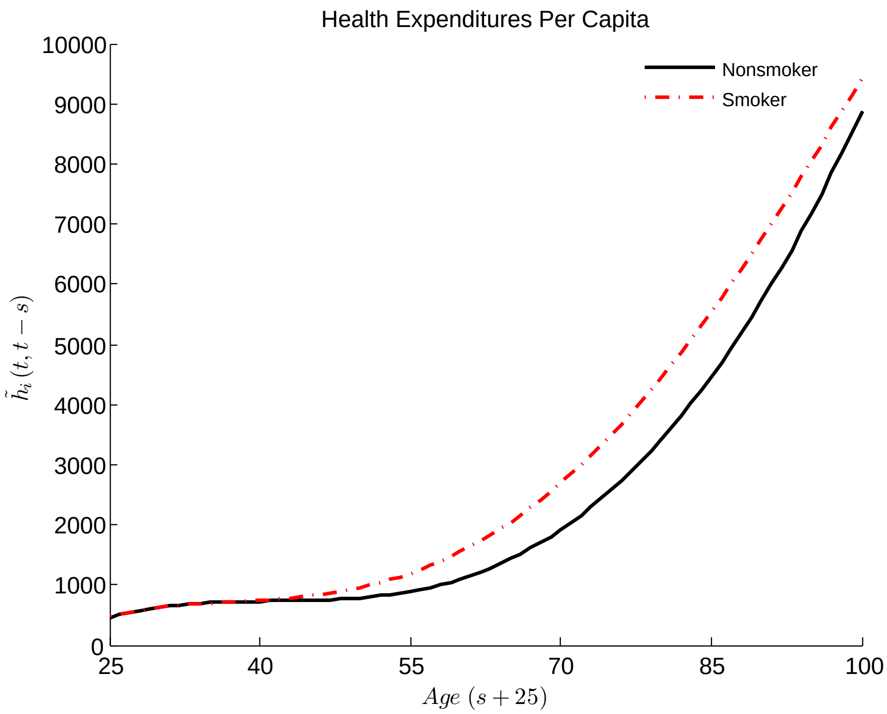

Figure 4: Health expenditures per capita $\widetilde{h}_i(s)$ measured in dollars.

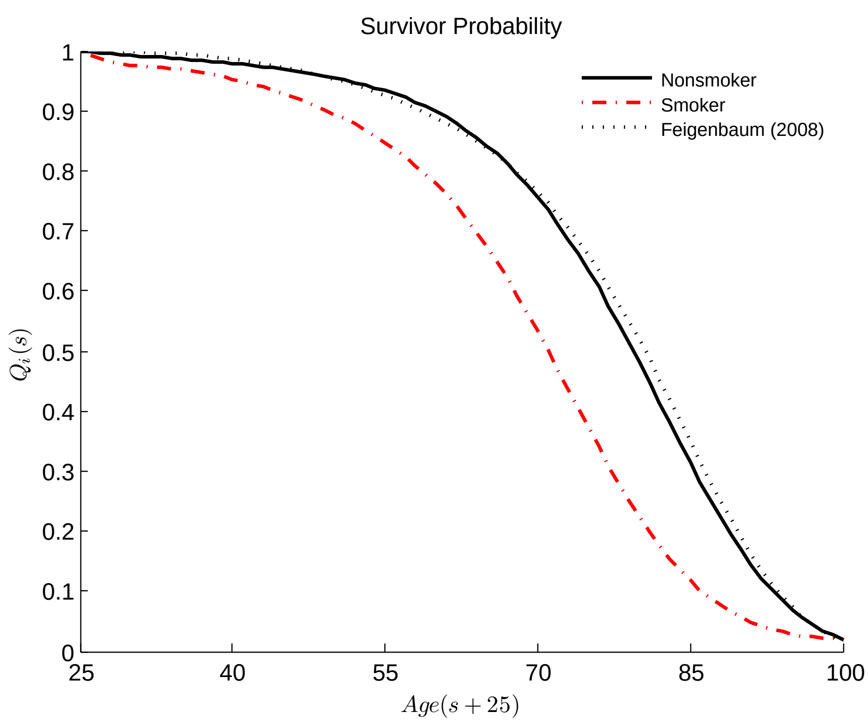

Figure 5: Survivor probabilities for nonsmokers and smokers. For comparison, the survivor probabilities in Feigenbaum (2008) are also given.

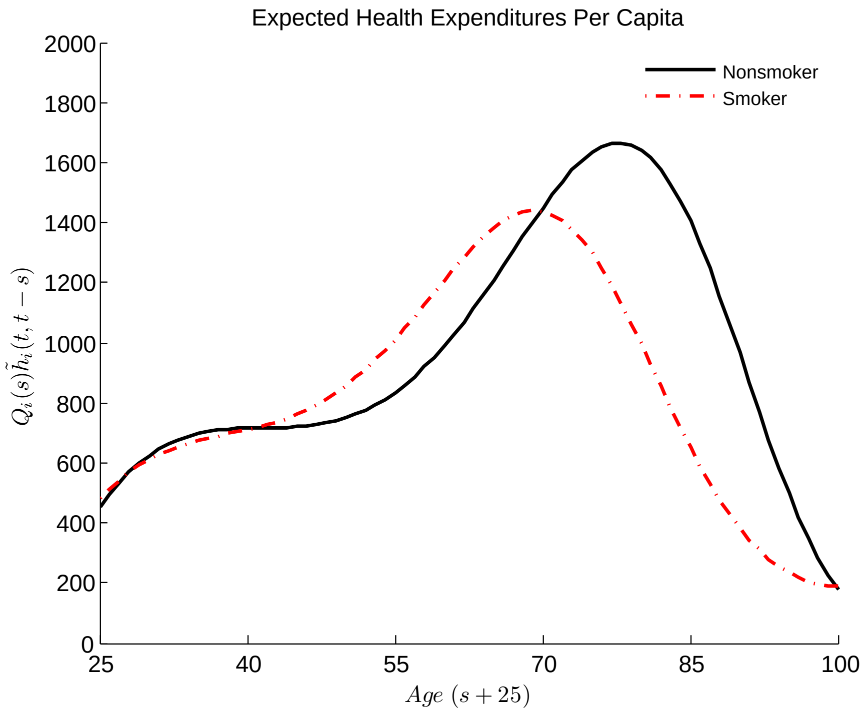

Figure 6: Expected health expenditures per capita $Q_i(t)\widetilde{h}_i(s)$ as a function of age.

The fitted health expenditures and survivor functions produce expected health expenditures $Q_i(s)\widetilde{h}_i(s)$ as a function of age for both types of households that are summed up in Fig. 6. Although expected health expenditures for smokers are higher at younger ages, they fall off later because smokers die faster. Conversely, expected health expenditures for nonsmokers are much larger than for smokers late in life with a peak in the early 80s. Since the area under the nonsmoker curve is larger than for the smoker curve, a nonsmoker ends up costing more than a smoker.[15]

To calibrate the preference and production parameters, we begin with the following macroeconomic targets. We set the share of capital $\alpha = 1/3$, the capital-output ratio to $K/Y = 3.0$, and the growth rate of technology to $g = 0.015$. We target shares of health and consumption expenditures to match $H/Y = 0.15$ and $C/Y = 0.7$ respectively. From the income-expenditure identity

$$Y = C + (\delta + g)K + H, \tag{20}$$

these choices imply $\delta = 0.035$. To calibrate the tax rates on income in our baseline model, we set $\tau_k = \tau_y$, which is a reasonable approximation to the existing tax system in the United States. With this method of financing, the health-care budget-balancing condition (for the case of $\rho = 0$) (equation (17)) changes to

$$H = \tau_y\,(wL + rK) = \tau_y Y_N,$$

where $Y_N = Y - \delta K$ is NDP. Also, with this specification, the baseline budget-balancing health-care tax rate is the ratio of aggregate health expenditures to Net Domestic Product (NDP):

$$\tau_y = \frac{H}{Y - \delta K} = \frac{\frac{H}{Y}}{1 - \delta\frac{K}{Y}} = \frac{0.15}{1 - (0.035)3} = 0.1676. \tag{21}$$

[15] Also note that Fig. 6 closely replicates the pattern observed by Barendregt et al. (1997).

Following Feigenbaum (2008), we set the Social Security tax rate to $\tau_{SS} = 0.106$. About 20% of the U.S. population smokes (Dube et al., 2009), so we calibrate the fraction of smokers in a newborn cohort to $f_S = 0.2$.

Next, we jointly calibrate the unobservable preference parameters and the lifecycle productivity profile. In particular, the shape of the lifecycle labor hours profile depends on the lifecycle productivity profile $e(s)$, which we assume for now is the same for both nonsmokers and smokers. Note that $e(s)$ represents the unconditional productivity profile, but unfortunately, we only directly observe the productivity profile conditional on households working, which is generally higher than the unconditional profile, especially at late ages when often only the most productive people continue to work. We address this problem by following the procedure of Bullard and Feigenbaum (2007).[16] We obtain data from the 2001 CPS on hourly income (normalized with respect to age 25) $\hat{e}(s)$ and also on cross-sectional hours per week $\widehat{L}(s)$, defined in the model as

$$L(s) = \frac{f_N Q_N(s)(1 - l_N(t, t-s)) + f_S Q_S(s)(1 - l_S(t, t-s))}{f_N Q_N(s) + f_S Q_S(s)}. \tag{22}$$

Instead of treating $\hat{e}(s)$ as the unconditional productivity profile, we view $e(s)$ as an unobserved structural parameter that we constrain to be close to $\hat{e}(s)$. We consider values of the inverse of intertemporal elasticity (γ) from within the range usually encountered in macroeconomics, and then for each γ-value we minimize the loss function

$$\begin{aligned} D(\theta) \quad = \quad & \sum_{s=0}^{T_L} \frac{1}{\sigma_L^2(s)} \left(L(s) - \widehat{L}(s) \right)^2 + \sum_{s=0}^{T_e} \frac{1}{\sigma_e^2(s)} \left(e(s) - \hat{e}(s) \right)^2 + \frac{1}{\sigma_{K/Y}^{10}} \left(\frac{K}{Y} - \widehat{\left(\frac{K}{Y} \right)} \right)^{10} \qquad (23) \\ & + \sum_{s=T_l+1}^{T} \sum_{i=N,S} \left(\frac{1 - l_i(t, t-s)}{\sigma_l} \right)^{10} \end{aligned}$$

with respect to the vector $\theta = \{\beta, \eta, e(0), e(5), e(15), e(20), e(27), e(35), e(45), e(55)\}$ of unobservable parameters.[17] Here we approximate $e(s)$ as a piecewise linear function with knots at actual ages 30, 40, 45, 52, 60, 70 and 80 (model ages 5, 15, 20, 27, 35, 45 and 55). In (23), $\sigma_L(s)$ and $\sigma_e(s)$ are the age-specific standard errors from the 2001 CPS data, and $T_L = 55$ and $T_e = 35$ are the maximum ages for which data are available in the respective series.[18]

The results of the minimization exercise and the corresponding macroeconomic observables for baseline equilibria with $f_S = 0.2$ are listed in Table 1. The corresponding productivity profiles are plotted in Fig. 7 and the equilibrium cross-sectional labor hours profiles are plotted in Fig. 8. Given that we have the lowest value of the loss function (23) under $\gamma = 6$, we treat the bold-faced row in Table 1 as our baseline calibration.

[16] Here we disregard lifecycle consumption data, which is primarily because our model is not well suited to match data along this dimension. This should not be surprising, as Feigenbaum (2008) and Hansen and İmrohoroğlu (2008) demonstrate that it is very difficult to match the lifecycle consumption profile in Gourinchas and Parker (2002) using a general equilibrium lifecycle consumption model with Social Security. This is because Social Security crowds out private saving, requiring significantly higher interest rates in general equilibrium. Higher interest rates lead to consumption increasing much faster in early life, because of which the model consumption profiles have larger peaks that occur significantly later than what is found in data.

[17] By construction, $D(\theta)$ has the form of a likelihood function, where we view $\widehat{L}(s)$ and $\widehat{e}(s)$ as observations of $L(s)$ and $e(s)$ respectively with corresponding measurement errors that have variances $\sigma_L^2(s)$ and $\sigma_e^2(s)$. The third term involving K/Y is a penalty function that is close to zero for K/Y within $\sigma_{K/Y}$ of our target value $\widehat{(\frac{K}{Y})}$. Likewise, the fourth term penalizes parameterizations that result in households working long hours at late ages as can happen for smokers due to their low survival probability.

[18] We set $\sigma_{K/Y} = 0.3$, and set $\sigma_l = \frac{10}{168}$ to rule out the possibility of households working more than ten hours per week after age $T_l = 45$.

γ	γ_c	β	η	n_h	K/Y	H/Y	C/Y	τ_y	$D(\theta)$
Data					3.00	0.150	0.700	-	-
1	1.00	0.97	0.183	0.0000361	2.76	0.151	0.711	0.1676	1.7×10^7
4	1.56	0.996	0.188	0.0000401	2.78	0.151	0.701	0.1676	1601
6	**1.94**	**1.005**	**0.187**	**0.0000362**	**2.72**	**0.152**	**0.712**	**0.1676**	**1249**
10	2.73	1.037	0.192	0.0000377	2.73	0.152	0.712	0.1676	1364

Table 1: Parameters and values of targeted observables for various choices of γ. The baseline calibration is in bold face.

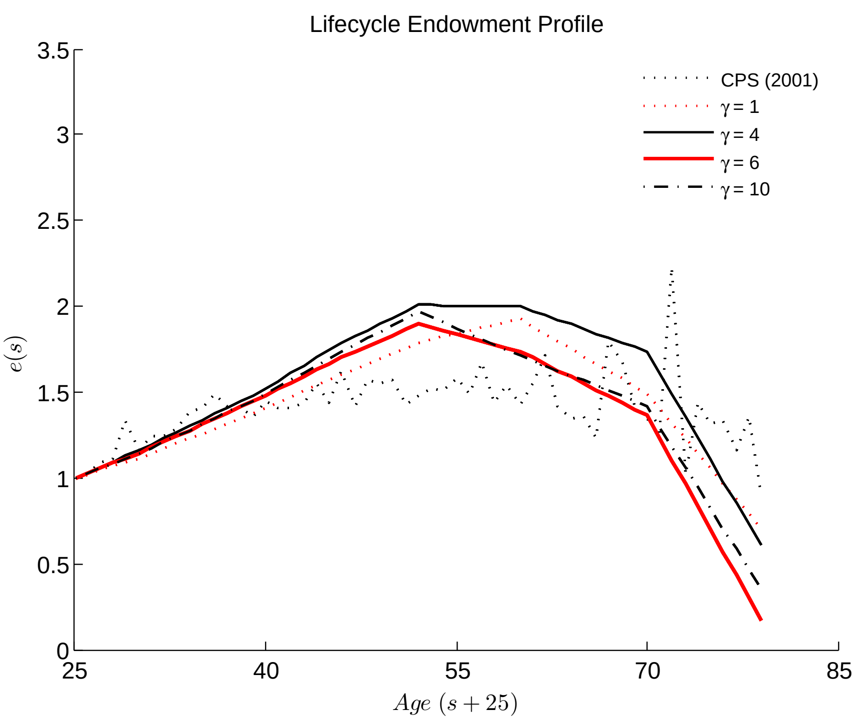

Figure 7: Calibration of the lifecycle productivity profile $e(s)$ for the different γ-values along with CPS data. The solid red curve for $\gamma = 6$ is the baseline calibration.

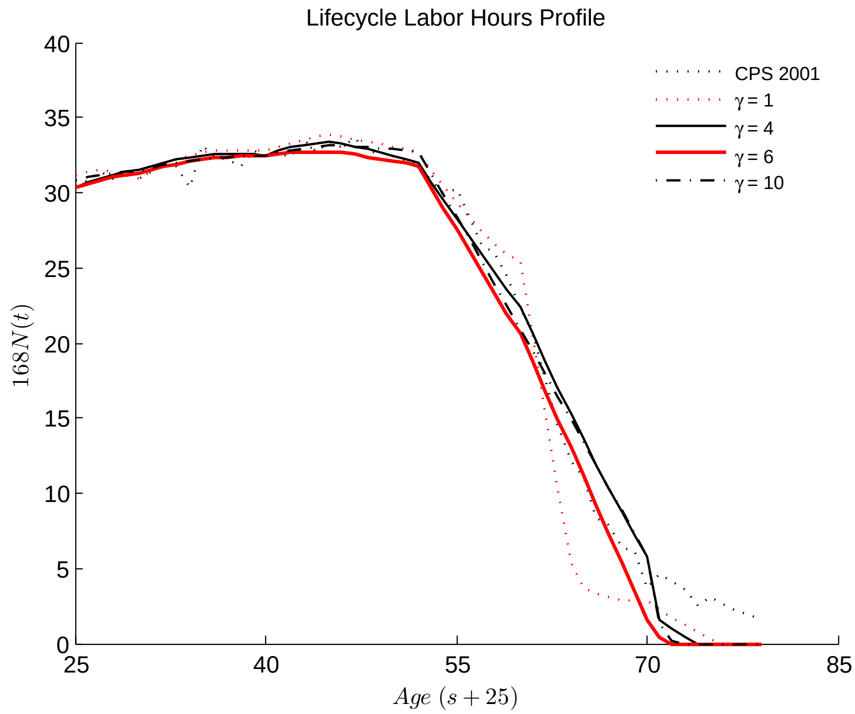

Figure 8: Cross-sectional mean of labor hours for the different γ-values along with CPS data. The solid red curve for $\gamma = 6$ is for the baseline calibration.

Note that in models where labor supply is endogenous, γ is the inverse intertemporal elasticity of the consumption-leisure bundle. To measure the inverse intertemporal elasticity of consumption, leisure must be held constant, which implies that

$$\gamma_c = 1 - (1 - \gamma)\eta. \tag{24}$$

Although we do not calibrate the model to match lifecycle saving behavior, the differences in labor supply over the lifecycle, along with differences in life expectancy, have significant implications for household saving. The average cross-sectional asset holding of nonsmokers is about 117% larger than that of smokers, which gets magnified to 127% once we account for the differences in survivorship between the two groups. To show this, we plot in Fig. 10 the expected cross-sectional assets holdings by household type under the baseline calibration. This difference in saving over the lifecycle will prove important when we eliminate smoking from our calibrated model.

5 Baseline Results from the Elimination of Smoking

Given our data on the survival probabilities and the age-specific health expenditures for the two household types, we find that if we set $f_S = 0$, then aggregate health expenditures increase by 2.72%. The effect of setting $f_S = 0$ on the budget-balancing health-care tax rate, however, depends on how the tax base or NDP changes with it. The most naïve analysis would assume that households supply labor inelastically until they retire at age 65, and that there is no difference in saving between the two types of households. While the population would increase by 3.18% if we eliminate smoking, the labor supply would increase by only 1.17% since most of the difference in life expectancy between nonsmokers and smokers does not occur till after the peak productivity years prior to age 55.

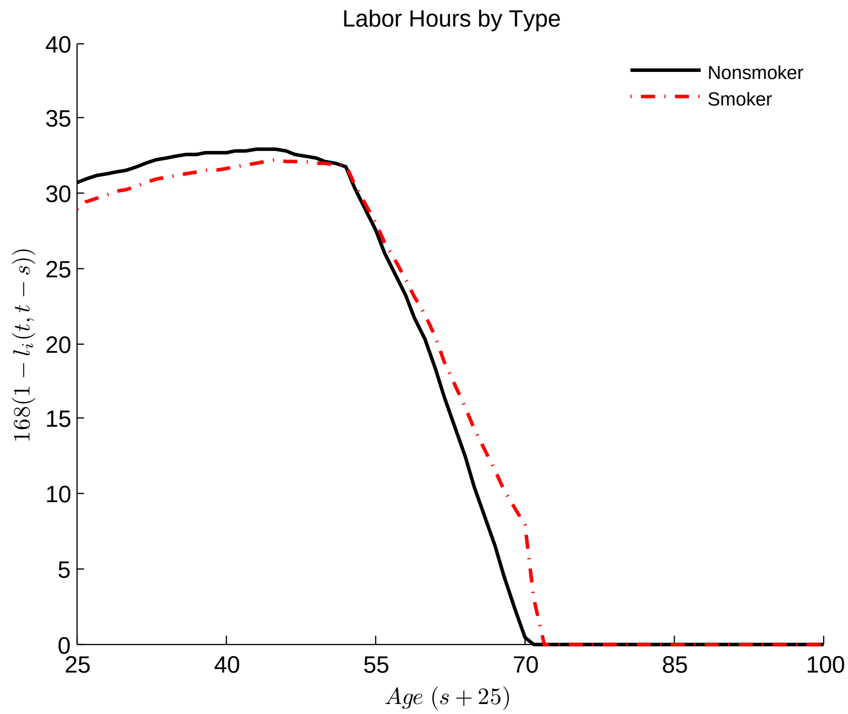

Figure 9: Labor hours by type as a function of age for the baseline calibration.

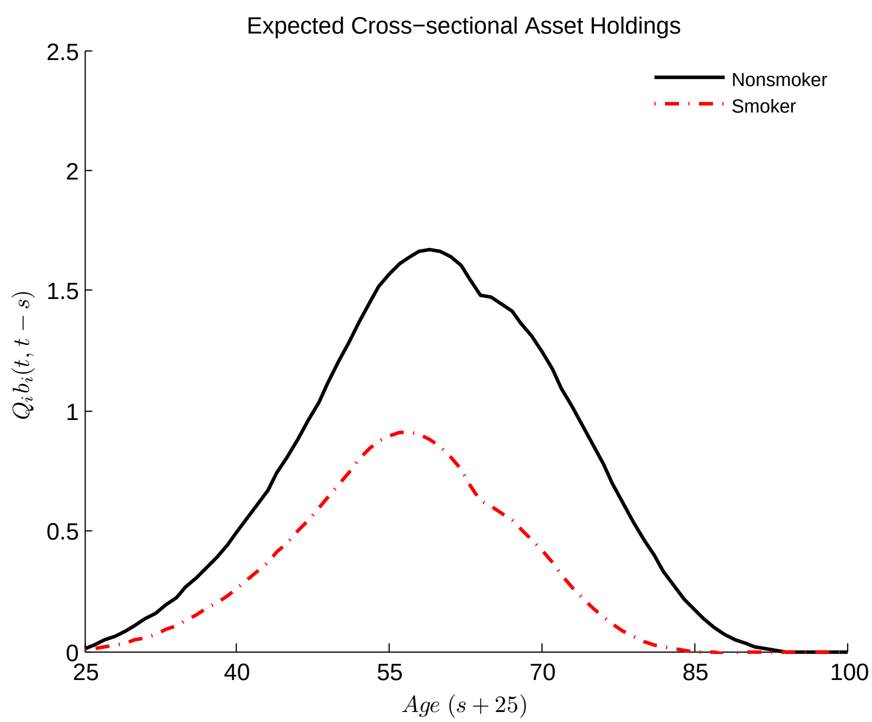

Figure 10: Expected cross-sectional asset holdings by type as a function of age for the baseline calibration.

K/Y	H/Y	C/Y	τ_y	$\frac{\Delta H}{H}$	$\frac{\Delta Y}{Y}$	$\frac{\Delta K}{K}$	$\frac{\Delta L}{L}$	$\frac{\Delta Y_N}{Y_N}$	$\frac{\Delta \tau_y}{\tau_y}$
2.80	0.149	0.711	0.1652	2.72%	4.47%	7.28%	3.10%	4.18%	−1.40%

Table 2: Key observables and their percentage changes as a consequence of changing f_S from 0.2 to 0.

Holding the capital stock fixed, this increase in labor supply would imply an increase in NDP of only 0.89%, which is much smaller than the 2.72% increase in health expenditures. Thus it would appear to a casual observer that taxes would have to rise to pay for the higher medical expenditures of nonsmokers.

What the preceding analysis ignores is that (i) smokers and nonsmokers will not work the same amount; (ii) smokers and nonsmokers will save differently; and (iii) factor prices will be different in a world without smokers, which will further alter the labor and saving choices of nonsmokers.

The general-equilibrium effect of eliminating smoking for our baseline calibration is reported in Table 2. Labor supply increases by slightly over 3% with the elimination of smoking. Note that there are three factors that contribute to this increase in labor supply: a pure increase in survival probabilities, an increase in hours per week over the lifecycle, and finally the interaction between the lifecycle allocation of hours per week with the age-dependent productivity profile. This increase decomposes into roughly 0.95 percentage points from the change in survival probabilities, and 2 percentage points from nonsmokers working an average of 19 minutes more per week over the lifecycle from the baseline. This leaves an additional 0.35 percentage points that comes from the interaction of hours per week with the variation in productivity over the lifecycle. As is shown in Fig. 11, nonsmokers supply fewer hours per week prior to age 40, but supply more thereafter until retirement when smoking is eliminated. Given that the age-dependent productivity profile increases steeply between ages 40 and 55, these reallocations in hours per week lead to an increase in aggregate labor supply that is more than what can be accounted for by the increased hours alone.

With the aggregate capital stock fixed at its baseline value, an increase of 3.1% in labor supply leads to an increase of 2.28% in NDP when we eliminate smoking. This is less than the 2.72% increase in health expenditures, so if we account only for the change in labor supply, the tax rate must go up to balance the health-care budget. However, as Table 2 shows, the elimination of smoking leads to an increase of 7.28% in the aggregate capital stock, which would go completely unnoticed in a model that does not account for the differences in saving behavior between nonsmokers and smokers. Accounting for both the increase in labor supply and the capital stock, we obtain a 4.18% increase in NDP, which is larger than the 2.72% increase in health expenditures. Therefore, we see that for our baseline calibration, the budget-balancing health-care tax rate decreases by about 1.4% with the elimination of smoking.

For our baseline calibration, changes in the aggregate labor supply and capital stock lead to a 3.7% decline in the interest rate and a roughly 1.3% increase in the wage rate. How important are these changes in factor prices for the resulting change in NDP? In Table 3, we report the fiscal consequences of eliminating smoking for an open economy version of our baseline model, where we hold the factor prices fixed at their initial equilibrium values under $f_S = 0.2$. Note that we still set the taxes to balance the government's budget constraints, and also ensure that the bequest-balance equation is satisfied. The partial equilibrium changes in Table 3 are much larger than the general equilibrium changes identified in Table 2. General equilibrium effects greatly mitigate the effect of eliminating smoking, because the reduction in the equilibrium interest rate that occurs in general equilibrium substantially curtails the increase in saving, which is slightly over 20% for our baseline calibration in partial equilibrium. On the other hand, the labor supply does not increase as much

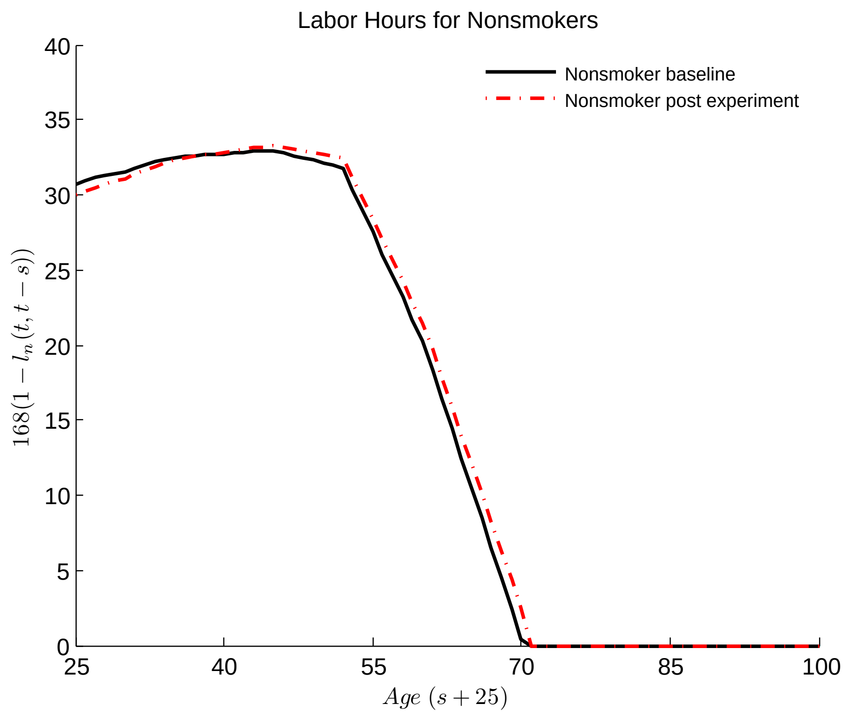

Figure 11: Labor hours for nonsmokers as a function of age in the baseline calibration and post experiment.

K/Y	H/Y	C/Y	τ_y	$\frac{\Delta H}{H}$	$\frac{\Delta Y}{Y}$	$\frac{\Delta K}{K}$	$\frac{\Delta L}{L}$	$\frac{\Delta Y_N}{Y_N}$	$\frac{\Delta \tau_y}{\tau_y}$
3.09	0.147	0.703	0.1637	2.72%	6.22%	20.4%	−0.25%	5.19%	−2.35%

Table 3: Key observables and their percentage changes as a consequence of changing f_S from 0.2 to 0, with factor prices held fixed at the equilibrium levels under $f_S = 0.2$.

K/Y	H/Y	C/Y	τ_y	$\frac{\Delta H}{H}$	$\frac{\Delta Y}{Y}$	$\frac{\Delta K}{K}$	$\frac{\Delta L}{L}$	$\frac{\Delta Y_N}{Y_N}$	$\frac{\Delta \tau_y}{\tau_y}$
2.81	0.15	0.71	0.1661	2.72%	3.85%	5.83%	2.88%	3.64%	−0.89%

Table 4: Key observables and their percentage changes as a consequence of changing f_S from 0.2 to 0 with $\gamma = 1$.

when factor prices are fixed. Indeed, the 20% increase in capital is so large that it brings with it enough of an increase in the accidental bequest that nonsmoking households actually work fewer hours after smoking is eliminated.

As we discussed earlier, to calibrate the baseline model, we consider values of the inverse of intertemporal elasticity (γ) from within the range usually encountered in macroeconomics, and then minimize the value of the loss function (23) with respect to the discount factor (β), the consumption share parameter (η), and the knots in the unconditional productivity profile $e(s)$ for each $\gamma-$value. This process yields the data in Table 1 as the optimal parameter values. It is clear from the table that the optimal value of the discount factor is $\beta = 1.005$, implying a negative discount rate of -0.5%, which happens to be somewhat uncommon in the literature.[19] However, while minimizing the loss function we do encounter a set of parameter values in which the discount factor is less than unity, so the discount rate is positive. With $\gamma = 1$, the discount factor is $\beta = 0.97$, which implies a discount rate of about 3% (see Table 1). The set of parameter values with $\gamma = 1$ does not minimize the loss function in (23) because the model predicts counterfactual lifecycle labor hours profiles under these values. If a household of type i works both at age s and $s+1$, then how rapidly leisure changes between the two ages is given by

$$\frac{l_i(t+s+1,t)}{l_i(t+s,t)} = \left(\frac{(1+g)e(s+1)}{e(s)}\right)^{\frac{\eta(1-\gamma)-1}{\gamma}} \left(\frac{Q_i(s+1)}{Q_i(s)}\beta(1+(1-\tau_k)r)\right)^{1/\gamma}, \tag{25}$$

which is directly proportional to how rapidly survivorship changes between the two ages. For smokers, the rate at which survival probabilities decline shoots up at around age 60, so the leisure profile declines and the labor profile increases sharply. Because smokers heavily discount the possibility of surviving to age 60, they do not put much value on their leisure after age 60. Thus smokers will work much more than nonsmokers if they manage to survive that long. This effect is proportional to the elasticity of intertemporal substitution γ^{-1}. For a low value of $\gamma = 1$, the model predicts smokers ought to be working fifty hours a week in their nineties. Since we do not observe such behavior, the data focus our attention on values of γ much larger than unity.

How different are the consequences of eliminating smoking if we consider the parameter values under $\gamma = 1$ in Table 1 as the baseline calibration? The results of our experiment of setting $f_S = 0$ with $\gamma = 1$ are reported in Table 4. For this alternative calibration, elimination of smoking still leads to the health-care tax rate declining. The increase in labor supply is smaller in this case: 2.9% compared to the 3.1% increase under $\gamma = 6$, and so is the increase in capital: 5.8% compared to the 7.3% increase under $\gamma = 6$. However, these changes lead to an expansion of roughly 3.6% in the NDP, which more than compensates for the 2.7% increase in the health-care expenditures, resulting in a 0.9% drop in the tax rate.[20]

[19]Studies that use models calibrated with negative discount rates include Huggett (1996); Huggett and Ventura (1999); Nishiyama and Smetters (2005); Bullard and Feigenbaum (2007), and Conesa and Garriga (2008).

[20]For the other calibrations reported in Section 4, the tax rate also drops as a consequence of eliminating smokers: for $\gamma = 4$, the tax rate drops by 1.4%, and for $\gamma = 10$ it drops by 1.7%.

6 Additional Fiscal Transfers

Thus far we have assumed smokers and nonsmokers are equally productive, though evidence suggests this is not the case, because we did not want to bias our initial results against smoking. However, the degree to which one type may subsidize the other is also important for this analysis. As we pointed out earlier, if smokers only pay for smokers' health care, and nonsmokers only pay for nonsmokers' health care, then there is no issue. A convenient way to measure the fiscal transfers occurring between the two groups is to compare the share of each group in the aggregate health expenditures to its share in the total health-care tax revenues. For our baseline calibration, nonsmokers account for 82.2% of aggregate health expenditures, but their share of total health-care tax revenues is 83.2%. On the other hand, smokers account for 17.8% of the aggregate health expenditures, but contribute only 16.8% in the total health-care tax revenues. This indicates positive fiscal transfers going from the nonsmokers to the smokers in our baseline calibration.

However, if smokers are less productive than nonsmokers, there may be additional fiscal transfers that work in the opposite direction. Two relevant sources of such transfers in the U.S. are the benefit-earnings link in Social Security, and progressive income taxes. In the baseline model, we had assumed that both nonsmokers and smokers receive the same Social Security benefit. However, in the U.S., Social Security benefits are positively linked to work-life income. If nonsmokers supply more labor over the lifecycle, both because they are more productive, and also because they work more hours per week and retire later, then with a positive benefit-earnings link, the Social Security benefit of a nonsmoker will likely be larger than that of a smoker. Likewise, if the income tax code is progressive, as it is in the U.S., then the effective tax rate that nonsmokers pay to finance health-care will likely be larger. Conceivably, if smokers are subsidizing nonsmokers through these mechanisms, our previous results might be overturned and smoking could be a fiscal good. In this section we verify the robustness of our baseline results by introducing these additional fiscal transfers between the two groups.

6.1 Social Security Benefit-Earnings Link

To capture the fiscal transfers that might occur between nonsmokers and smokers through Social Security, we consider two changes to our baseline model. First, we let nonsmokers and smokers differ in productivity. Specifically, we assume that households entering the model as smokers experience a permanent productivity shock φ (< 1), which implies that now $e_S(s) < e_N(s) \forall s$. We calibrate the productivity shock using data on observed wage differentials between nonsmokers and smokers. Second, we let Social Security benefits positively depend on work-life income through a benefit-earnings rule identical to the one that we observe in the U.S. The differences in benefits between nonsmokers and smokers coming from this rule will account for the differences in productivity, as well as the differences in labor supply over the lifecycle, between the two groups.

Using data from the National Longitudinal Survey of Youth, Levine et al. (1997) find that even after accounting for the differences in individual characteristics that are likely to be correlated with both smoking and wages, smokers' wages are 4-8% lower than that of nonsmokers on the average.[21] We use this information to set the permanent shock to the productivity of a smoking household to $\varphi = 0.94$. Because of this shock, the lifecycle productivity profiles of the nonsmokers and smokers now diverge (See Figure 12).

Next, we incorporate the U.S. benefit-earnings rule into our baseline model. In the U.S., Social

[21] This is presumably because smokers take more breaks, are more prone to illness, and are less physically fit. Productivity differences might play a role in a persons choice of whether to take up smoking. However, that possibility is beyond the scope of this paper to examine since we do not model the smoking decision.

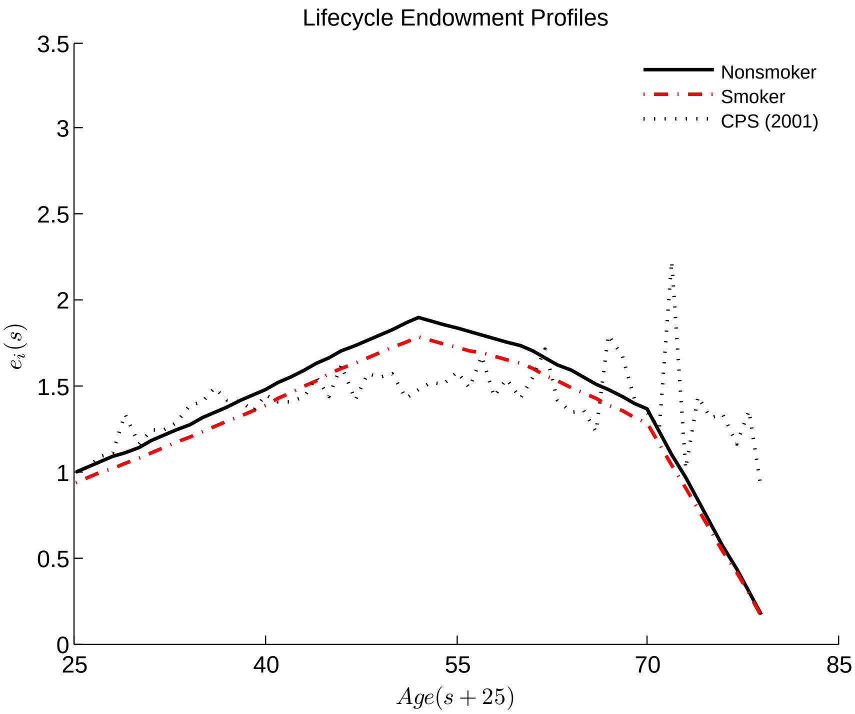

Figure 12: Lifecycle productivity profiles for nonsmokers and smokers when the smokers receive a permanent productivity shock $\varphi = 0.94$.

Security benefits are positively linked to work-life income. The Social Security Administration (SSA) calculates what is known as the Average Indexed Monthly Earnings (AIME) for every covered individual, which is a measure of average work-life income. The benefit, also known as the Primary Insurance Amount (PIA), is calculated as a fraction of the AIME. This fraction is known as the replacement rate. The replacement rate is a piecewise constant function of the AIME that decreases discontinuously at each "bend point", so the benefit rule is progressive. This results in a benefit function that is piecewise increasing and concave as shown in Figure 13.[22]

To incorporate this benefit-earnings rule into our baseline model, we first compute the average work-life income (AWI) for both smokers and nonsmokers using the formula

$$AWI_i(t) = \frac{1}{T_{l_i=1}} \left\{ \sum_{s=0}^{T_{l_i=1}} \{1 - l_i(t, t-s)\} \, w(t) e_i(s) \right\}. \tag{26}$$

Then, we compute the average AWI in the economy, and calculate the Social Security benefits based on the bend points of the U.S. benefit-earnings rule.

After making these two changes in our baseline model, we compute a new equilibrium, while holding all the other parameters fixed at their initial baseline values. Note that given our equilibrium definition, the health-care and the Social Security taxes are chosen to balance the government budgets. The macroeconomic observables for this new baseline equilibrium with $f_S = 0.2$ are listed in Table 5.

As the table shows, the macroeconomic observables in the new baseline equilibrium with the productivity differentials and the U.S. benefit-earnings rule are virtually indistinguishable from

[22]See Huggett and Ventura (1999) for more details.

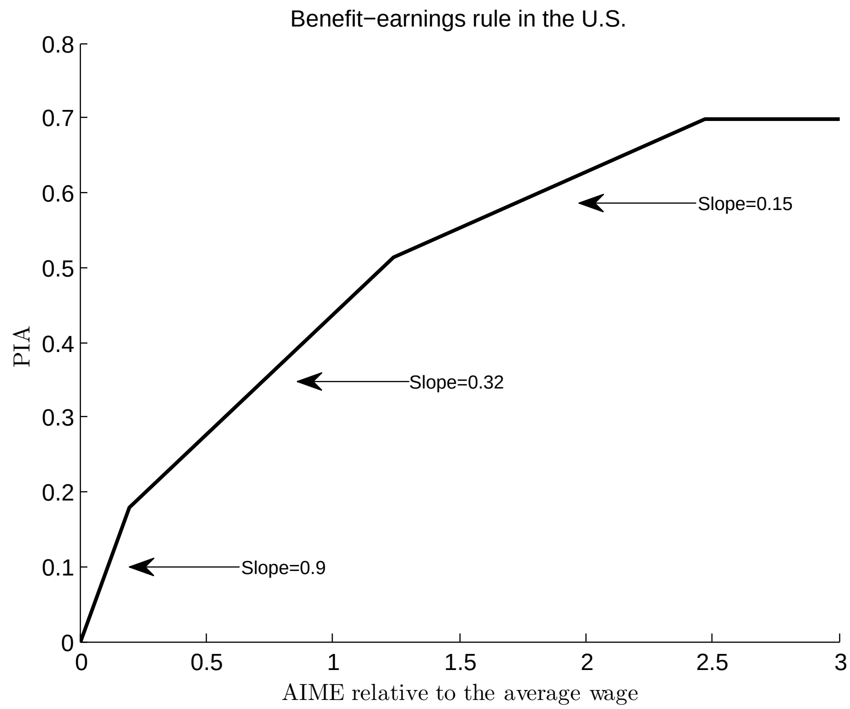

Figure 13: Benefit formula in the U.S.

γ	γ_c	β	η	n_h	K/Y	H/Y	C/Y	τ_y
Data					3.00	0.150	0.700	-
6	1.94	1.005	0.187	0.0000362	2.72	0.153	0.711	0.1695

Table 5: Parameters and values of macroeconomic observables in the new baseline with the productivity differentials and the U.S. benefit-earnings rule.

K/Y	H/Y	C/Y	τ_y	$\frac{\Delta H}{H}$	$\frac{\Delta Y}{Y}$	$\frac{\Delta K}{K}$	$\frac{\Delta L}{L}$	$\frac{\Delta Y_N}{Y_N}$	$\frac{\Delta \tau_y}{\tau_y}$
2.80	0.149	0.711	0.1653	2.72%	5.67%	8.60%	4.23%	5.36%	−2.51%

Table 6: Key observables and their percentage changes as a consequence of changing f_S from 0.2 to 0, with the productivity differentials and the U.S. benefit-earnings rule.

those in the initial baseline. The changes are also small at the household level: averaged over the lifecycle, nonsmokers now work roughly 15 minutes per week less than the smokers, which is only marginally smaller than the 21 minute difference in the initial baseline. There is no change in retirement behavior, as the smokers continue to delay retirement by a year even in this case. However, because of the productivity differential, nonsmoker labor supply is now roughly 12% larger than smoker labor supply, which was only 5% larger in the initial baseline. This difference in labor supply between the two groups also affects their Social Security benefits, as they are now positively related to work-life income. The PIA of a nonsmoker is roughly 5% larger than that of a nonsmoker, but the replacement rate experienced by a nonsmoker is about 34%, which is slightly less than the smoker replacement rate of 35%.

To see how these innovations in the baseline model affect the size and direction of the fiscal transfers occurring between the nonsmokers and smokers, we compare the share of each group in the aggregate health expenditures to its share in the total health-care tax revenues for the new baseline. Nonsmokers still account for 82.2% of aggregate health expenditures, but their share of total health-care tax revenues now increases to 84.2%. On the other hand, smokers still account for 17.8% of the aggregate health expenditures, but their contribution in the total health-care tax revenues falls by a percentage point to 15.8%. Therefore, the fiscal transfers going from the nonsmokers to smokers are even stronger in this augmented model. This should not be surprising, as now the tax payments of the smokers are even lower, because the productivity shock permanently reduces their wages.

The effects of eliminating smoking from the baseline model augmented with the productivity differentials and the U.S. benefit-earnings rule for Social Security are reported in Table 6. It is clear from the table that smoking is a fiscal bad even in this case. In fact, the budget-balancing health-care tax rate for this model declines by 2.5% with the elimination of smoking, which is larger than the 1.4% decline for the baseline model. This is consistent with the fact that the fiscal transfers from the nonsmokers to the smokers occurring through the health-care program are even stronger in this model.

6.2 Progressive Labor Income Taxes

Another important source of fiscal transfers between nonsmokers and smokers could be the progressive income tax code in the U.S. Because of this progressivity, the marginal tax rates experienced by households with higher current labor income are usually higher than those experienced by households with lower current labor income. However, in all the experiments so far we have assumed that the progressivity parameter $\rho = 0$, which implies that the marginal tax rates are identical across household types in the model.[23] In this section we calibrate the progressivity parameter to the U.S. income tax code, which leads to the nonsmokers and smokers experiencing different marginal tax rates on labor income.

To calibrate the progressivity parameter ρ, we fit a linear function to the 2012 tax rate schedule

[23]For details on how to solve the model with $\rho > 0$, see Bagchi and Feigenbaum (2012).

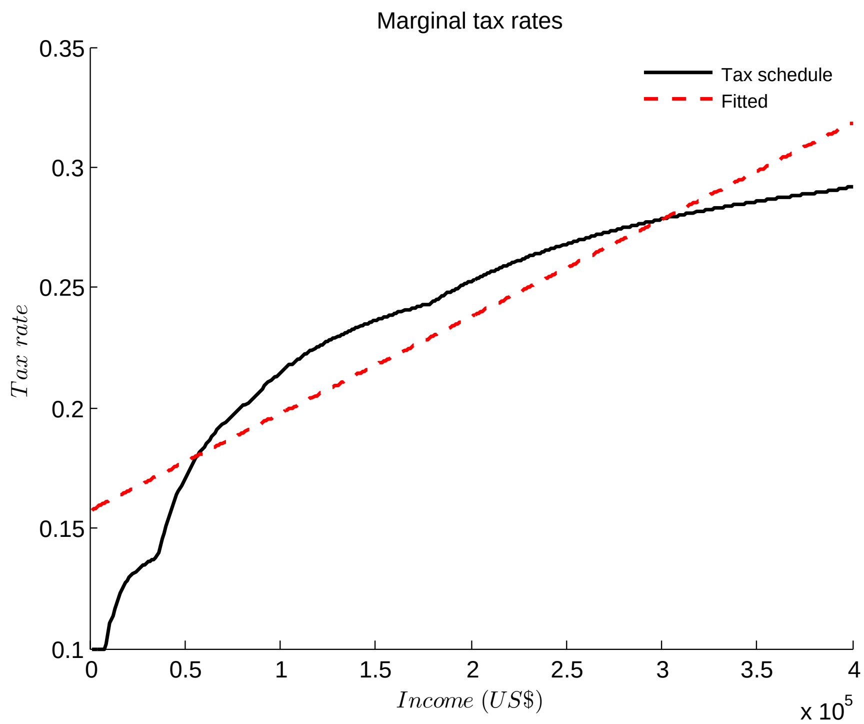

Figure 14: The U.S. single filer base tax schedule compared with the linear fit.

γ	γ_c	β	η	n_h	K/Y	H/Y	C/Y	τ_y
Data					3.00	0.150	0.700	-
6	1.94	1.005	0.187	0.0000362	2.73	0.153	0.707	0.1658

Table 7: Parameters and values of macroeconomic observables in the new baseline with the progressive labor income tax.

for a single filer in the U.S., which gives

$$\widehat{Taxrate} = 0.157219(1 + 2.5647 \times 10^{-7} y). \tag{27}$$

Therefore, the estimated progressivity parameter is $\hat{\rho} = 2.5647 \times 10^{-6}$. However, note that income in the real world is measured in dollars, so we need to convert $\hat{\rho}$ to model units. To do this, we calculate the ratio of average household income in the U.S. in 2012 to average cross-sectional income in the model, which comes out to roughly 4.3×10^4, and then normalize $\hat{\rho}$ to get

$$\rho = (4.3 \times 10^4) \times (2.5647 \times 10^{-6}) \approx 0.1. \tag{28}$$

The linear fit is compared to the current U.S. single filer tax rate schedule in Figure 14.

After setting $\rho = 0.1$ in our baseline model, we compute a new equilibrium, while holding all the other parameters fixed at their initial baseline values. Similar to the previous experiment, we set the health-care and the Social Security taxes to balance the government budgets. The macroeconomic observables for this new baseline equilibrium with progressive taxes and $f_S = 0.2$ are listed in Table 7.

It is clear from the table that a progressive labor income tax has almost no effect on the equilibrium values of the macroeconomic observables. When averaged over the lifecycle, nonsmoker

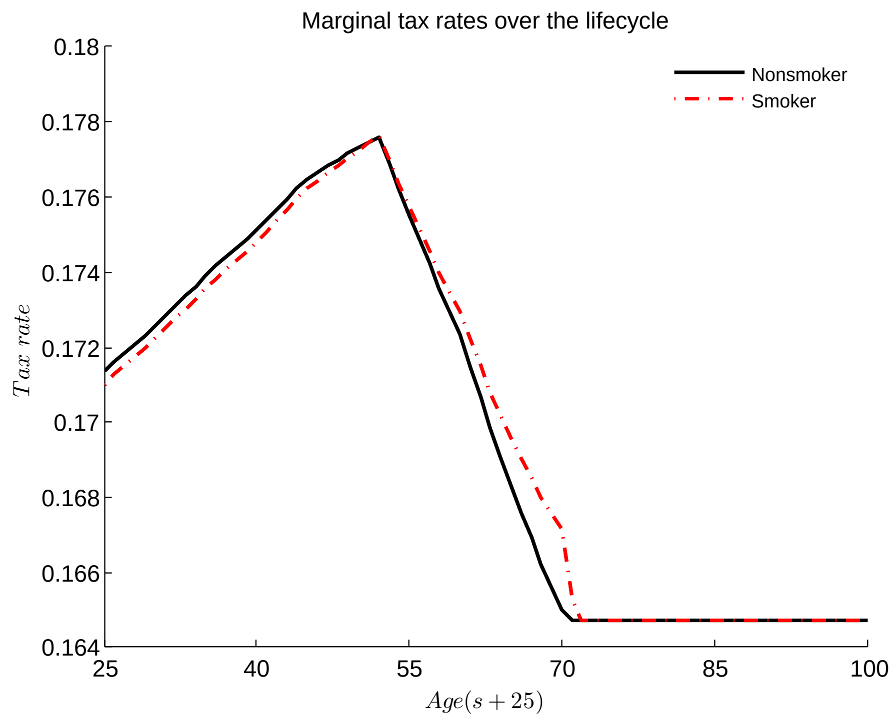

Figure 15: Marginal tax rates by household type for the baseline calibration with progressive labor income taxes.

K/Y	H/Y	C/Y	τ_y	$\frac{\Delta H}{H}$	$\frac{\Delta Y}{Y}$	$\frac{\Delta K}{K}$	$\frac{\Delta L}{L}$	$\frac{\Delta \tau_y}{\tau_y}$
2.81	0.151	0.71	0.1634	2.72%	4.45%	7.27%	3.07%	−1.44%

Table 8: Key observables and their percentage changes as a consequence of changing f_S from 0.2 to 0, with the progressive labor income taxes.

hours per week are about 19 minutes lower than the smoker hours per week, which is slightly lesser than the 21 minute difference in the baseline model without progressive taxes. Smokers retire a year later, and because now the marginal tax rates depend on income (which depends on labor supply), nonsmokers experience higher marginal tax rates until about age 51, after which they cross over (see Figure 15). Averaging over the work life, the marginal tax rate for a nonsmoking household is virtually identical to that of a smoking household.

With a progressive labor income tax, nonsmokers' share of total health-care tax revenues is 83.1%, which is almost identical to that in the baseline model, and they still account for 82.2% of aggregate health-care expenditures. Therefore, the fiscal transfers between the two groups in this model are almost identical to what we had in the initial equilibrium.

We report the macroeconomic effects of eliminating smoking from the baseline model with progressive labor income taxes in Table 8. The budget-balancing health-care tax rate now declines by 1.44%, which is slightly larger than the 1.4% decline in the baseline model. This is because with progressive taxes, the expansion in the health-care tax base due to the elimination of smoking is 4.22%, which is slightly larger than the 4.18% increase in the baseline model.

Therefore, we find that even after incorporating productivity differentials, a benefit-earnings link in Social Security, and progressive labor income taxes in our baseline model, elimination of

K/Y	H/Y	C/Y	$\frac{\Delta H}{H}$	$\frac{\Delta Y_N}{Y_N}$	$\frac{\Delta \tau_y}{\tau_y}$	$\frac{\Delta b}{b}$	EV_n
2.80	0.149	0.711	2.72%	4.18%	−1.40%	−4.05%	0.79%

Table 9: Welfare effect of the elimination of smoking.

K/Y	H/Y	C/Y	$\frac{\Delta H}{H}$	$\frac{\Delta K}{K}$	$\frac{\Delta L}{L}$	$\frac{\Delta Y_N}{Y_N}$	$\frac{\Delta \tau_y}{\tau_y}$	$\frac{\Delta \tau_{SS}}{\tau_{SS}}$	EV_n
2.77	0.151	0.711	2.72%	5.32%	2.49%	3.22%	−0.49%	5.28%	−0.36%

Table 10: Key observables and percent changes relative to the baseline model with a fixed Social Security benefit.

smoking always leads to a decline in the budget-balancing health-care tax rate. The expansion in the health-care tax base is always larger than the percentage increase in aggregate health expenditures in general equilibrium.

7 Welfare Consequences

So far our focus has been entirely on the fiscal effect of the elimination of smoking. What exactly are the welfare consequences of our experiment? Note that there is no simple way to compare the welfare of smoking and nonsmoking households, and it is not meaningful to inquire into the welfare of households that do not exist after the experiment. Therefore, our metric for evaluating the welfare consequences of the elimination of smoking is the equivalent variation (EV_N) of nonsmokers, which is the percentage by which consumption would have to be increased at each age for a nonsmoking household in a mixed population consisting of 20% smokers (M) to have the same lifetime utility as a nonsmoking household absent any smokers (NS):

$$\begin{aligned} & \sum_{s=0}^{T} Q_N(s)\beta^s u\big(\big(c_N^M(t+s,t)\,(1+EV_N)\big)^\eta\, l_N^M(t+s,t)^{1-\eta};\gamma\big) \qquad (29) \\ = & \sum_{s=0}^{T} Q_N(s)\beta^s u\big(\big(c_N^{NS}(t+s,t)\big)^\eta\, l_N^{NS}(t+s,t)^{1-\eta};\gamma\big) \end{aligned}$$

We report in Table 9 the equivalent variation of eliminating smokers from our initial baseline calibration, and also the percentage change in the Social Security benefit.

It is clear from Table 9 that the equivalent variation for nonsmokers and the percentage change in the health-care tax rate have exactly opposite signs. This is expected, as a lower health-care tax rates impose a smaller distortion on the behavior of nonsmoker households.

Thus far we have maintained the assumption that the Social Security administration imposes a fixed tax on labor earnings. As the labor supply and worker-to-retiree ratio vary, it is the benefit-per-retiree that adjusts to maintain a balanced Social Security budget. Depending on the political situation, the government might alternatively mandate that the benefit should remain unchanged and adjust the payroll tax rate τ_{SS} accordingly. Table 10 reports the general-equilibrium effects of setting $f_S = 0$ in the initial baseline, when the benefits are held fixed and the payroll tax rate adjusts to balance the Social Security budget.

With respect to the observable values, the changes with a fixed Social Security benefit are qualitatively similar to the changes with a fixed payroll tax rate. However, since taxes are higher after the experiment with fixed benefits, both the labor supply and the capital stock do not increase as much. Nevertheless, the budget-balancing health-care tax rate still decreases, albeit by a smaller amount. In this case, the lifetime utility of nonsmokers also decreases. This ought to be expected, though, since Social Security plays no positive role in this model. Expanding the program must necessarily hurt the households.

To sum up, the welfare effect of eliminating smoking depends on how the Social Security program responds to this change. When the payroll tax rate is fixed but the benefit is allowed to adjust to the elimination of smoking, welfare increases. However, when the benefit is held fixed and the payroll tax rate is allowed to adjust, welfare decreases.

8 Conclusions

Although it costs more to maintain the health of a smoker than it does to maintain a nonsmoker, because nonsmokers live longer they end up being more costly than smokers over the lifecycle. Here we take data on survival probabilities and average health expenditures, separated by smoking status, and construct a general equilibrium model to analyze whether the higher per-person cost of maintaining a nonsmoker would translate into higher taxes, assuming health expenditures are paid for by the government, or lower utility. We find the elimination of smoking leads to a reduction in the budget-balancing health-care tax rate. The welfare consequences of eliminating smoking depend on how the Social Security program adjusts to this change. If the Social Security payroll tax is left unchanged and the benefit is allowed to fall, the decrease in the health-care tax rate makes households better off. If, however, the benefit is kept fixed and the payroll tax is raised, households are worse off.

One issue that we have not treated here is the transition path from a steady state where some of the population smokes to a steady state where none of the population smokes. If we suppose that the economy begins with 20% smokers and then suddenly all new generations are born without smokers, one would expect that initially the budget-balancing tax rate will decrease for all regimes. While the tax base will begin to increase at once, health expenditures will initially fall since the higher health expenditures of nonsmokers will not show up until they get very old. However, while nonsmoking households may be better off in the long run, it is not clear that all nonsmokers will enjoy higher utility during the transition. Some early cohorts may suffer from low interest rates when they get old without enjoying the benefits of a higher capital that has not accumulated yet when they are young.

A Solving the Model

It is helpful to break the problem into an intertemporal and intratemporal problem. Let us define total expenditures on goods, both leisure and consumption, as

$$E_i(t+s,t) = (1-\tau_{ss}-\tau_y)w(t+s)l_i(t+s,t)e_i(s) + c_i(t+s,t) \tag{30}$$

for an agent of type i at age s who is born at t. We further define

$$V(E, p_c, p_l) = \max_{c,l} u(c^\eta l^{1-\eta}, \gamma) \tag{31}$$

subject to

$$c + p_l l = E \tag{32}$$

$$0 \le l \le 1.$$

This has the solution

$$c(E,p_l)=\begin{cases}\eta E & E<\frac{p_l}{1-\eta}\\ E-p_l & E\geq\frac{p_l}{1-\eta}\end{cases}\tag{33}$$

and

$$l(E,p_l)=\begin{cases}\frac{(1-\eta)E}{p_l} & E<\frac{p_l}{1-\eta}\\ 1 & E\geq\frac{p_l}{1-\eta}\end{cases}.\tag{34}$$

Note that both functions are continuous across the boundary $E=\frac{p_l}{1-\eta}$.

The value function is

$$V(E,p_l)=\begin{cases}u\left(\eta^{\eta}\left(1-\eta\right)^{1-\eta}E;\gamma\right) & E<\frac{p_l}{1-\eta}\\ u\left(\left(E-p_l\right)^{\eta};\gamma\right) & E\geq\frac{p_l}{1-\eta}\end{cases}.\tag{35}$$

Its first derivative with respect to E is

$$V_E(E,p_l)=\begin{cases}\frac{\eta^{\eta(1-\gamma)}(1-\eta)^{(1-\eta)(1-\gamma)}}{p_l^{1-\eta}}E^{-\gamma} & E<\frac{p_l}{1-\eta}\\ \eta\left(E-p_l\right)^{\eta-1-\gamma\eta} & E\geq\frac{p_l}{1-\eta}\end{cases}.$$

Let M be the inverse of V_E given p_l:

$$M(x,p_l)=\begin{cases}\left(\left[\eta^{\eta}\left(1-\eta\right)^{1-\eta}\right]^{\gamma-1}x\right)^{-\frac{1}{\gamma}} & x>v^*(p_l)\\ \left(\frac{x}{\eta}\right)^{-\frac{1}{1-\eta+\gamma\eta}}+p_l & x\leq v^*(p_l)\end{cases},\tag{36}$$

where

$$v^*(p_l)=\eta^{\eta(1-\gamma)}\left(\frac{1-\eta}{p_l}\right)^{1-\eta+\gamma\eta}.\tag{37}$$

All of these results carry over to the special case with exogenous labor, i.e. when $\eta=1$. In that case, we always have

$$E<\frac{p_l}{1-\eta}=\infty,$$

and

$$c(E,p_l)=E\tag{38}$$

$$l(E,p_l)=0.\tag{39}$$

The Lagrangian for the intertemporal problem is

$$\begin{aligned}\mathcal{L}_i =& \sum_{s=0}^{T}\{Q_i(s)\beta^s V\left(E_i(t+s,t),(1-\tau_{ss}-\tau_y)w(t+s)e_i(s)\right)\\ &+\lambda_i(t+s,t)\left[(1-\tau_{SS}-\tau_y)w(t+s)e_i(s)+[1+(1-\tau_k)r]k_i(t+s,t)\right.\\ &\left.+\ B(t+s)+\Theta(s-T_r)b(t+s)-E_i(t+s,t)\right]\}\end{aligned}\tag{40}$$

The first-order conditions are

$$\frac{\partial\mathcal{L}_i}{\partial E_i(t+s,t)}=Q_i(s)\beta^s V_E(E_i(t+s,t),(1-\tau_{ss}-\tau_y)w(t+s)e_i(s))-\lambda_i(t+s,t)=0\tag{41}$$

and

$$\frac{\partial \mathcal{L}_i}{\partial k_i(t+s+1,t)} = -\lambda_i(t+s,t) + \lambda_i(t+s+1,t)[1+(1-\tau_k)r] = 0, \tag{42}$$

from which we have

$$\lambda_i(t+s,t) = \frac{\lambda_i(t,t)}{(1+(1-\tau_k)r)^s}, \tag{43}$$

and

$$E_i(t+s,t) = M\left(\frac{\lambda_i(t,t)}{Q_i(s)\left(\beta(1+(1-\tau_k)r)\right)^s}, (1-\tau_{ss}-\tau_y)w(t+s)e_i(s)\right). \tag{44}$$

Finally, we determine $\lambda_i(t,t)$ from the lifetime budget constraint using the boundary conditions $k_i(t,t) = k_i(t+T+1,t) = 0$, which is

$$\sum_{s=0}^{T} \frac{E_i(t+s,t)}{[1+(1-\tau_k)r]^s} = \sum_{s=0}^{T} \frac{(1-\tau_{SS}-\tau_y)w(t+s)e_i(s) + B(t+s) + \Theta(s-T_r)b(t+s)}{[1+(1-\tau_k)r]^s}. \tag{45}$$

This is simply the condition that the present value of expenditures over the lifecycle should be equal to that of income.

References

Anger, Silke, Michael Kvasnicka, and Thomas Siedler (2011), "One last puff? Public smoking bans and smoking behavior." *Journal of Health Economics*, 30, 591–601.

Attanasio, Orazio, Sagiri Kitao, and Giovanni L. Violante (2010), *Financing Medicare: A General Equilibrium Analysis*, 333–366. University of Chicago Press.

Auld, M. Christopher (2005), "Causal Effect of Early Initiation on Adolescent Smoking Patterns." *The Canadian Journal of Economics*, 38, 709–734.

Bagchi, Shantanu and James Feigenbaum (2012), "Optimal Income-Tax Progressivity in a Continuous-Time Overlapping-Generations Model." *Working Paper*.

Barendregt, Jan J., Luc Bonneux, and Paul J. van der Maas (1997), "The health care costs of smoking." *New England Journal of Medicine*, 337, 1052–1057.

Bishop, John A. and Jang H. Yoo (1985), ""Health Scare," Excise Taxes and Advertising Ban in the Cigarette Demand and Supply." *Southern Economic Journal*, 52, 402–411.

Buddelmeyer, Hielke and Roger Wilkins (2005), "The Effects of Smoking Ban Regulations on Individual Smoking Rates." *IZA Discussion Papers Series*, Working Paper 1737.

Bullard, James and James Feigenbaum (2007), "A leisurely reading of the life-cycle consumption data." *Journal of Monetary Economics*, 54, 2305–2320.

Conesa, Juan C. and Carlos Garriga (2008), "Optimal Fiscal Policy In The Design Of Social Security Reforms." *International Economic Review*, 49, 291–318.

De Nardi, Mariacristina, Eric French, and John Bailey Jones (2009), "Life Expectancy and Old Age Savings." *NBER Working Paper Series*, Working Paper 14653.

DeCicca, Philip, Don Kenkel, and Alan Mathios (2008), "Cigarette taxes and the transition from youth to adult smoking: Smoking initiation, cessation, and participation." *Journal of Health Economics*, 27, 904–917.

Domeij, David and Magnus Johannesson (2006), "Consumption and Health." *The B.E. Journal of Macroeconomics*, 0, 6.

Dube, S.R., K. Asman, A. Malarcher, and R. Carabollo (2009), "Cigarette Smoking Among Adults and Trends in Smoking Cessation - United States, 2008." *MMWR Weekly*, 58, 1227–1232.

Farkas, Arthur J., Elizabeth A. Gilpin, Martha M. White, and John P. Pierce (2000), "Association Between Household and Workplace Smoking Restrictions and Adolescent Smoking." *JAMA: The Journal of the American Medical Association*, 284, 717–722.

Feigenbaum, James (2008), "Can mortality risk explain the consumption hump?" *Journal of Macroeconomics*, 30, 844–872.

French, Eric and John Bailey Jones (2011), "The Effects of Health Insurance and Self-Insurance on Retirement Behavior." *Econometrica*, 79, 693–732.

Gourinchas, P.-O. and J. A. Parker (2002), "Consumption over the Life Cycle." *Econometrica*, 70, 47–89.

Halliday, Timothy, Hui He, and Hao Zhang (2009), "Health Investment over the Life-Cycle." *IZA Discussion Papers Series*, Working Paper 4482.

Hansen, Gary and Selahattin İmrohoroğlu (2008), "Consumption over the Life Cycle: The Role of Annuities." *Review of Economic Dynamics*, 11, 566–583.

He, Hui (2010), "Welfare Cost of Medicare." *Working Paper.*

Huang, Kevin X. D. and Gregory W. Huffman (2010), "A Defense of the Current US Tax Treatment of Employer-Provided Medical Insurance." *Department of Economics Working Papers, Vanderbilt University.*

Huggett, Mark (1996), "Wealth distribution in life-cycle economies." *Journal of Monetary Economics*, 38, 469–494.

Huggett, Mark and Gustavo Ventura (1999), "On the Distributional Effects of Social Security Reform." *Review of Economic Dynamics*, 2, 498–531.

Jeske, Karsten and Sagiri Kitao (2009), "U.S. tax policy and health insurance demand: Can a regressive policy improve welfare?" *Journal of Monetary Economics*, 56, 210–221.

Jha, Prabhat, Binu Jacob, Vendhan Gajalakshmi, Prakash C. Gupta, Neeraj Dhingra, Rajesh Kumar, Dhirendra N. Sinha, Rajesh P. Dikshit, Dillip K. Parida, Rajeev Kamadod, Jillian Boreham, and Richard Peto (2008), "A Nationally Representative Case - Control Study of Smoking and Death in India." *New England Journal of Medicine*, 358, 1137–1147.

Jung, Juergen and Chung Tran (2010), "Health Care Financing over the Life Cycle, Universal Medical Vouchers and Welfare." *Working Paper.*

Kopecky, Karen A. and Tatyana Koreshkova (2009), "The Impact of Medical and Nursing Home Expenses and Social Insurance Policies on Savings and Inequality." *MPRA Working Paper.*

Levine, Phillip B., Tara A. Gustafson, and Ann D. Velenchik (1997), "More Bad News for Smokers? The Effects of Cigarette Smoking on Wages." *Industrial and Labor Relations Review*, 50, 493–509.

Levy, David T., K. Michael Cummings, and Andrew Hyland (2000), "A simulation of the Effects of Youth Initiation Policies on Overall Cigarette Use." *American Journal of Public Health*, 90, 1311–1314.

Lewit, E. M., A. Hyland, N. Kerrebrock, and K. M. Cummings (1997), "Price, public policy, and smoking in young people." *Tobacco Control*, 6, S17–S24.

Nishiyama, Shinichi and Kent Smetters (2005), "Does Social Security Privatization Produce Efficiency Gains?" Working Paper 11622, National Bureau of Economic Research.

Pentz, M. A., B. R. Brannon, V. L. Charlin, E. J. Barrett, D. P. MacKinnon, and B. R. Flay (1989), "The power of policy: the relationship of smoking policy to adolescent smoking." *American Journal of Public Health*, 79, 857–862.

Rogers, Richard G. and Eve Powell-Griner (1991), "Life Expectancies of Cigarette Smokers and Nonsmokers in the United States." *Social Science and Medicine*, 32, 1151–1159.

Sheshinski, Eytan (2008), *The Economic Theory of Annuities*. Princeton University Press, Princeton NJ.

Thrasher, James F., Matthew C. Rousu, Rafael Anaya-Ocampo, Luz Myriam Reynales-Shigematsu, Arillo-Santillán Edna, and Mauricio Hernández-Ávila (2007), "Estimating the impact of different cigarette package warning label policies: The auction method." *Addictive Behaviors*, 32, 2916–2925.

Viscusi, W. Kip (2009), "The New Cigarette Paternalism." *Regulation*, 26, 58–64.

Wakefield, M., B. Flay, M. Nichter, and G. Giovino (2003), "Effects of Anti-Smoking Advertising on Youth Smoking: A Review." *Journal of Health Communication*, 8, 229–247.

Zhao, Kai (2011), "Social security and the rise in health spending: a macroeconomic analysis." *MPRA Working Paper*.