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Taxation and anti-smoking campaigns: Complementary policies in tobacco control

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Abstract

We examine the optimal design of policies directed at regulating tobacco consumption through two types of instruments: taxation and anti-smoking mass media campaigns. We find that the main role of taxation is to correct for the population-average internal costs of smoking, while anti-smoking campaigns serve a complementary role. Namely, they add to the social welfare benefits of tobacco regulation as they are relatively more effective than taxation at discouraging smoking by individuals characterized by low degrees of self-control and high smoke-related health

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1. Introduction

Many countries routinely implement policy interventions to regulate tobacco consumption. Historically, taxation has been the main instrument used by governments, initially just

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as a revenue-raising device, subsequently also as a mean to limit tobacco consumption.[1] More recently, smoking prevention policies such as information-campaign programs about smoke-related diseases have gained importance in complementing taxation as tobacco control policies.[2] The empirical evidence reported in Section 2 shows that anti-smoking campaigns play an important role in tobacco control, complementing that of taxation. However, while the theoretical underpinnings of tobacco taxation have a long history, those of prevention policies are still limited.[3] The main purpose of this paper is to investigate how a non-price regulatory instrument adds to and interacts with taxation in the design of tobacco control policies.

We develop a framework in which a policy maker can use two types of regulatory instruments: (i) an *excise tax* that discourages tobacco consumption by increasing its price, and (ii) *anti-smoking campaigns* that affect consumption by inducing individuals to be more self-controlled when taking smoking decisions. We consider a population of consumers that are heterogeneous along several dimensions, such as the intensity of preferences for smoking, the size of future health harms caused by tobacco consumption, the degree of self-control in smoking, and the responsiveness to anti-smoking mass media campaigns. Our theoretical model of smoking behavior extends O'Donoghue and Rabin (2005, 2006) and Kőszegi (2005) — who examine the socially optimal level of taxation of a harmful good that is consumed by individuals lacking self-control — by explicitly considering the role of anti-smoking campaigns in regulating tobacco consumption.[4]

Our normative analysis shows how anti-smoking mass media campaigns can usefully complement taxation in controlling tobacco consumption. Ideally, a set of individual-specific taxes would allow to implement the first best, hence making other instruments redundant. However, individual-specific taxes are unfeasible in practice, because of lack of information and high administrative costs. Therefore, policy makers rely on second-best uniform taxation, which in turn calls for the introduction of additional policy instruments targeting specific inefficiencies. Prevention programs are useful in mitigating these inefficiencies.

Second-best efficient taxation requires a tax rate equal to the population average marginal health costs that smokers fail to internalize into their consumption decisions because of lack of self-control. This benchmark rate needs then to be adjusted depending on the degree of heterogeneity in smokers' responses to the tax induced price increase.[5] Nonetheless, as taxation mainly addresses the average 'internalities', additional policy instruments can be

[1] In the UK, excise duty on tobacco was first introduced in 1660 (Report on tobacco taxation in the United Kingdom, WHO). In the U.S.A., the first federal excise tax on tobacco products was introduced in 1862, while the first state tax was introduced in Iowa in 1921 (Tax Foundation). The Australian government has imposed an excise tax on tobacco products since 1901 (Australian Government, The Department of Health).

[2] Other instruments — such as smoke-free-air laws, smoking bans, and restrictions on youth access to tobacco products — are also widely used. Restrictions on advertising seem particularly important, given the impact of cigarette advertising on U.S. cigarette demand (see Goel, 2009).

[3] A notable exception is the theoretical model by Adda and Cornaglia (2010), which is used to build an empirical analysis on the interplay between smoking bans and taxes to limit passive smoking.

[4] Although our analysis is framed in terms of tobacco products, it can be extended to other types of harmful goods, like alcoholic drinks, drugs, or unhealthy food.

[5] Being based on the characteristics of the 'average' smoker, the benchmark tax rate does not properly account for individuals' heterogeneity in terms of health harms and degrees of self-control. A mark-up over the benchmark rate turns out to be optimal when smokers suffering above-average internal costs (higher health harms, or lower degrees of self-control) are more reactive to taxation than those experiencing below-average internal costs.

useful to better account for consumers' heterogeneity. In particular, the usage of anti-smoking campaigns determines more diversified responses than those implied by taxation for individuals with different internal costs of smoking. The ability to better account for agents' heterogeneity implies social welfare gains that justify in themselves the introduction of anti-smoking campaigns.

The implications we derive in terms of the optimal structure of regulation policy are clear-cut. Whenever it is optimal to use both instruments, the second-best optimal tax rate — where taxation is joined by prevention programs to regulate tobacco consumption — is lower than the third-best optimal tax rate — where only taxation is used. Indeed, the non-price instrument crowds-out the price instrument.

The rest of the paper is organized as follows. Section 2 reviews the literature on tobacco regulation and provides descriptive evidence on the relevance of taxation and prevention programs in tobacco control policies. Our theoretical model is introduced in Section 3. Section 4 defines individual and social welfare and examines the optimal structure of tobacco regulation policies. Section 5 calibrates the theoretical model to empirical data, leading to novel insights in terms of policy making. Section 6 concludes.

2. Related literature, stylized facts, and policy issue

Most of the available theoretical literature focuses on the role of taxation in regulating tobacco consumption. There are at least three 'traditional' arguments in favor of tobacco taxation. First, it is simple to administer, and it constitutes a good source of tax revenue both at the central and at the sub-central levels of government. Second, it represents a straightforward way to have smokers paying for the pecuniary externalities they impose on society due to the extra health care costs associated to the treatment of smoking related diseases. Third, according to a paternalistic view, it helps discouraging tobacco consumption, seen as a harmful good that would otherwise be consumed in excessive quantities by 'boundedly rational' consumers.

There are also 'traditional' arguments against tobacco taxation. For instance, the paternalistic view has been forcefully criticized by Becker and Murphy (1988) based on the idea of rational addiction, according to which smoking habits are the result of optimizing choices by rational agents. Moreover, it has been argued that the burden of tobacco taxation is regressive (and hence problematic on equity grounds; see, e.g., Gospodinov & Irvine, 2009), since cigarettes consumption accounts for a larger share of the income of poor households.

A recent literature has both revisited and challenged the pros and cons of tobacco taxation (e.g., Gruber, 2001, Gruber & Kőszegi, 2008; U.S. National Cancer Institute and World Health Organization (2016), Ch. 4, for comprehensive non-technical surveys). The idea that smokers may not behave in a fully rational way has been reconsidered using the theory of intertemporal choices with hyperbolic discounting (on the latter, see, among others, Laibson, 1997). Gruber and Kőszegi (2004) and O'Donoghue and Rabin (2006) provide a rigorous underpinning of the role that taxation can play in correcting time inconsistent choices by the consumers of a harmful good. Other contributions (e.g., Gruber & Kőszegi, 2008) have rejected the pecuniary externality argument in favor of tobacco taxation, holding that the burden imposed by smoking on

health care systems is approximately of the same magnitude as the savings on retirement expenditures, since smokers have a shorter life expectation than non-smokers.[6] Finally, some authors (e.g. Gruber & Kőszegi, 2004 and Kotakorpi, 2008) argued that the taxation of cigarettes consumption may show a burden profile that is progressive in welfare terms, rather than regressive. The intuition is simple. In a setting of time inconsistent behavior, tobacco taxation plays a corrective role by reducing over-consumption. However, since low-income consumers are more sensitive to tax induced price changes than high income consumers, taxation may turn out to benefit more the low than the high-income individuals, hence showing a progressive pattern in terms of welfare gains.

While the theoretical literature has focused mainly on the role of taxation, the empirical research has carefully also investigated the impact of non-price instruments on tobacco consumption.[7] Chaloupka and Wechsler (1997) examine how taxation and smoking restrictions in public places affect tobacco consumption by young adults, while Evans et al. (1999) focus on workplace smoking bans. Rousu et al. (2014) estimate the value for smokers of the information conveyed through warning labels on cigarettes packages. Xu et al. (2015) investigate the consequences of *Tips From Former Smokers* (Tips) — the first federally funded national mass media anti-smoking campaign launched in the U.S. in 2012 — finding robust evidence that the program has been cost-effective at successfully reducing morbidity and mortality associated to smoking. Also, a recent survey in U.S. National Cancer Institute and World Health Organization (2016, Ch. 8) has shown that information programs — including anti-smoking mass media campaigns — are necessary and effective tools in modern tobacco control policies, because of consumers' limited awareness about the risks of smoking.

There is abundant evidence on the diffusion of taxation and anti-smoking campaigns policies around the world. The Global Health Observatory (GHO) of the World Health Organization routinely computes categorical indicators about the level of taxes levied on cigarettes and the intensity and coverage of anti-smoking mass media campaigns in a number of countries. For both taxation and anti-smoking campaigns (see Appendix A.1 for the definition of each indicator), there is a specific indicator taking values $\iota \in \{2,3,4,5\}$, where higher values correspond to a progressively more intense usage of the instrument.[8] Table 1 shows, for both indicators, the number of countries for which the corresponding indicator takes a specific value in years 2010 and 2018 (the most recent available data). About 15% of the reporting countries (182 in 2010, 185 in 2018) barely use taxes ($\iota = 2$), with a total tax burden as a percentage of the price of cigarettes around 15% (as shown in the bottom part of Table 1, reporting the average tax rate for each category of the indicator). About two-thirds of the countries make a significant use of tobacco taxes ($\iota = 3,4$), while about 15% of them in 2010 and 20% in 2018 set taxes exceeding 75% of tobacco retail price ($\iota = 5$). Conversely, more than 50% of the countries make a limited use of anti-smoking

[6] See Crawford et al. (2010), for a critical assessment of the empirical literature on the estimation of the net social costs of smoking, as well as Bilgic et al. (2013) for an analysis of tobacco spending patterns and their health-related implications.

[7] Several empirical contributions deal with the impact of taxation on smoking habits as well. See, e.g., Chaloupka et al. (2012), and U.S. National Cancer Institute and World Health Organization, 2016, Ch. 4, for throughout accounts, as well as Escario and Molina (2004) for an analysis of optimally differentiated taxes on tobacco.

[8] A value $\iota = 1$ indicates that data are not reported or not categorized; hence we omit such occurrences from the analysis.

Table 1
Tobacco control policies indicators.

		distribution of countries on four-scale indicators				
		scores				
indicator	year	2	3	4	5	total
taxation	2010	29	63	62	28	182
taxation	2018	24	61	62	38	185
anti-smoking mass media campaigns	2010	97	9	28	35	169
anti-smoking mass media campaigns	2018	91	14	28	39	172
taxes as % of price of cigarettes	2010	15.2	36.2	63.5	79.7	48.8
taxes as % of price of cigarettes	2018	15.1	38.6	63.7	79.9	52.4

Source: WHO, Global Health Observatory

campaigns ($\iota = 2$), with the remaining countries being much more concentrated around the maximal value of the index rather than the central values.

The distribution of pairwise combinations of the two indicators is represented in Fig. 1a by means of a scatter plot, where the size of the circles is proportional to the total number of countries characterized by the corresponding pair of indicators (the number of countries, 163 in total, is also reported in the circles). Fig. 1a shows that countries exerting minimum or low effort ($\iota = 2{,}3$) on anti-smoking mass media campaigns are roughly uniformly distributed along the tax index, with a prevalence of central ($\iota = 3{,}4$) over extreme scores ($\iota = 2{,}5$). There are, however, 42 countries (26% of the total) that rely heavily both on taxation and anti-smoking campaigns, scoring 4 or 5 in both dimensions. As the figure shows, there is no evident correlation between the two policy instruments.

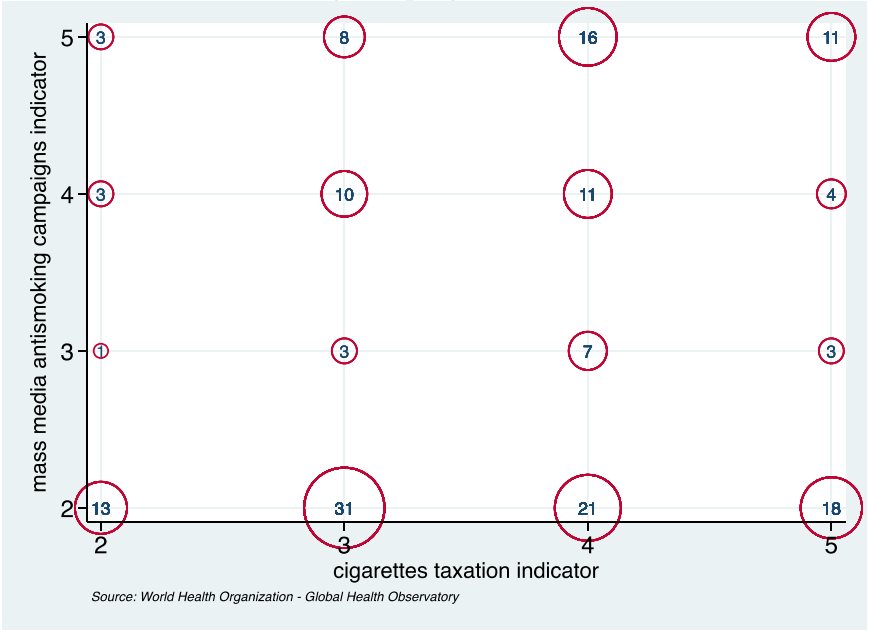
Figure 1b shows the scatter plot of total taxation as a percentage of the price of the most sold brands of cigarettes in 2010 and 2018 for a sample of 140 countries.[9] For 89 countries, 63% of the total, taxation is higher in 2018 than in 2010, while it is lower for 49 and unchanged for 2. The figure also shows that there are no clear patterns between the changes in the level of taxation and the changes in the intensity and coverage of anti-smoking mass media campaigns. The 44 countries that adopted more intense anti-smoking campaigns in 2018 than in 2010 (represented in blue) are not only those that increased taxation in the same period but also those that reduced it. The same observation holds for the 62 countries that did not change (in green) and the 34 countries that reduced (in red) the intensity and coverage of anti-smoking campaigns programs over the period 2010–2018.

Overall, these data show that policy makers do not rely exclusively (or even primarily) on taxation to restrict tobacco consumption, although there is a large heterogeneity among countries both in the extent and in the mix of the adopted measures. Therefore, in a theoretical perspective, it is important to move beyond a framework that only focuses on the role of taxes, properly accounting for the usage of additional instruments as well and highlighting the implications of their interplay.

[9] The sample is composed of countries reporting data on both taxation and anti-smoking campaigns in both years considered.

a

Taxation and Antismoking campaigns indicators (2018)



b

Taxation and Antismoking campaigns trends: 2010-2018

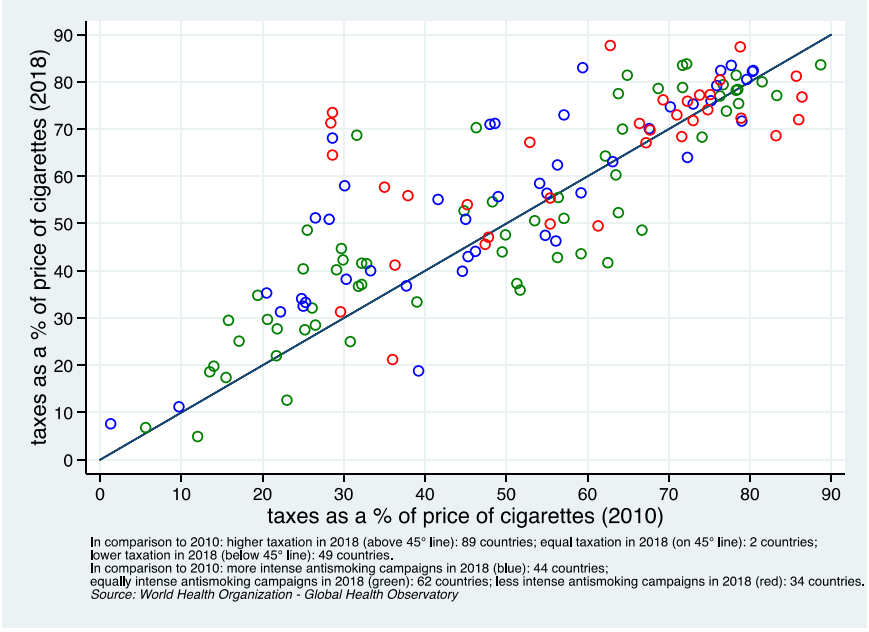


Fig. 1. a. Taxation and Antismoking campaigns indicators (2018). b. Taxation and Antismoking campaigns trends: 2010–2018.

3. The theoretical model

Our theoretical framework builds on O'Donoghue and Rabin (2005, 2006) and Kőszegi (2005), who investigate the role of taxation and anti-smoking mass media campaigns for controlling tobacco consumption.

3.1. Preferences, health costs, and anti-smoking campaigns

We consider individuals who consume two types of goods: tobacco, denoted by x, and a 'standard' consumption good, denoted by y. The utility function takes the form

$$u(x, y) = v(x;\boldsymbol{\rho}) + y - \beta(z;\mathbf{b})\delta\gamma x, \tag{1}$$

where $v(.)$ is a strictly concave function of x, such that $v_x \geq 0$ and $v_{xx} < 0$, and $\boldsymbol{\rho}$ is a vector of taste parameters allowing for heterogeneity among smokers about their preferences for tobacco consumption. To guarantee an interior solution in x, we assume that $\lim_{x\to 0} v_x = +\infty$, $\lim_{x\to +\infty} v_x = 0$.[10] Note that the utility function (1) is linear in y, implying that all income effects fall on the demand of the standard consumption good.

The future harm for smokers' health, which is assumed to be proportional to the amount of current tobacco consumption, is captured by the third term of the utility function (1). The present value of future harm for each unit of current tobacco consumption is perceived by the consumer as being equal to $\beta\delta\gamma$, where the parameter $\gamma \geq 0$ is the value of health harm, $\delta \in (0,1)$ is the discount factor, and $\beta \in [0,1]$ is the quasi-hyperbolic discounting parameter, which captures in reduced form the degree of time inconsistency (or lack of self-control) in consumer behavior.[11] Note that $\beta < 1$ implies overconsumption with respect to the efficient level of consumption, whereas $\beta = 1$ implies fully rational behavior (more on this in Section 4.1). We assume that the parameter β can be positively affected by the amount of public spending $z \geq 0$ that finances mass media campaigns and prevention programs against smoking. As documented in Section 2, these are forms of regulation that are quite effective at curbing tobacco consumption. We formalize this effect by assuming that the relationship between β and z is given by the function $\beta(z;\mathbf{b})$, where $\beta_z \geq 0$, $\beta_{zz} \leq 0$, and $\mathbf{b}$ is a vector of taste parameters that allows for heterogeneous individual responses to anti-smoking campaigns. The concavity of $\beta(.)$ in z has a natural interpretation. Since higher spending on anti-smoking campaigns means that consumers receive more information about health risks, we assume that a consumer's degree of self-control β does not decrease with z. However, since the production of 'effective' information occurs under decreasing returns, the marginal impact of higher spending z on β is non-increasing; i.e., the marginal impact on smokers' behavior of anti-smoking campaigns is a decreasing function of their frequency and intensity.

[10] For ease of analytical tractability, we consider a framework in which all individuals consume a positive amount of the harmful good. Non-smokers can be accommodated into the model by letting a group of individuals be characterized by a very steep marginal utility $v_x(.)$, so that their tobacco consumption, albeit positive, is negligible.

[11] The assumption that smokers may lack self-control (i.e., $\beta < 1$) while they are correctly informed about the true risks of tobacco use (i.e., the value of γ) is consistent with the evidence reported by Khwaja et al. (2009). Further issues about smokers' inter-temporal choices — risk preferences, time discounting, abilities to plan — are critically assessed in Khwaja et al. (2007a, 2007b), and Scott et al. (2014).

3.2. Individual consumption decisions

Both consumption goods are exchanged in perfectly competitive markets.[12] Production costs are linear, with marginal costs equal to average costs, normalized to one for both goods. Good y is the *numeraire*. The market price of good x is equal to $p = 1 + t$, where $t \geq 0$ is a specific (excise) tax on cigarettes consumption, levied on producers.

Each individual is endowed with an exogenously given income I. The consumer's budget constraint is thus equal to $px + y \leq I$. By substituting $y = I - px$ into Eq. (1), the utility function can be expressed as a function of tobacco consumption only, i.e.

$$u(x) = v(x;\boldsymbol{\rho}) - (1 + t + \beta(z;\mathbf{b})\delta\gamma)x + I. \tag{2}$$

The first order condition for maximizing the utility function with respect to x can be written as[13]

$$v_x(x;\boldsymbol{\rho}) = 1 + t + \beta(z;\mathbf{b})\delta\gamma, \tag{3}$$

from which we obtain $\tilde{x}(t, z) > 0$ as a unique solution. By substituting the smoker's consumption $\tilde{x}$ into Eq. (2), we obtain the consumer's indirect utility function

$$\tilde{u}(t, z) = v(\tilde{x};\boldsymbol{\rho}) - (1 + t + \beta(z;\mathbf{b})\delta\gamma)\tilde{x} + I. \tag{4}$$

4. Social welfare and optimal policy

4.1. Individual welfare

Utility function (2), by representing a smoker's utility *at the time when smoking takes place,* is the appropriate one to carry out a positive analysis of smokers' actual behavior. However, as argued by Kőszegi (2005), for the normative analysis of tobacco regulation a different welfare measure is required. According to Kőszegi (2005), a smoker typically looks at tobacco consumption from at least two different perspectives. On the one hand, she takes decisions about *current* consumption. On the other hand, she makes resolutions about *future* tobacco consumption.

Hence, the utility function when consumption takes place is, in general, different than the one the individual uses when planning consumption. To properly account for the peculiarities of smokers' choices about tobacco consumption, and consistently with a consolidated literature on the optimal taxation of sin goods (e.g., Gruber & Kőszegi, 2004, Kőszegi, 2005, O'Donoghue & Rabin, 2006), we rely on the following utility function to study optimal tobacco regulation:

$$w(x) = v(x;\boldsymbol{\rho}) - (1 + t + \delta\gamma)x + I. \tag{5}$$

What distinguishes utility functions (2) and (5) is the presence, in the former, of the quasi-hyperbolic discounting parameter β (Laibson, 1997; O'Donoghue & Rabin, 1999) in front of the

[12] We focus on perfectly competitive markets, despite the fact that cigarettes' manufacturers typically have market power, as our goal is to investigate how the policy instruments can be used to correct for inefficient consumers' behavior. We briefly discuss the implications of producers' market power in Section 6.

[13] Second order conditions for a maximum hold by strict concavity of the utility function (2).

health costs the smoker will suffer in the future.[14] The framework of quasi-hyperbolic discounting refers to different 'selves' of the same individual in different time periods. When considering the optimal consumption of harmful goods she would like to undertake in the future, a self of the consumer (self I) trades-off future hedonic pleasure and future health costs at the discount factor δ. However, when the actual consumption choice is made, a different self of the same consumer ('self-II') trades-off current pleasure with future health damages at the quasi-hyperbolic discount factor $\beta\delta$. This implies, for $\beta < 1$, that the actual consumption of harmful goods made by 'self-II' is greater than that planned by 'self-I′, because the former has preferences that are biased in favor of immediate gratification and she behaves in an impatient, time inconsistent, manner (from the point of view of 'self-I′).

Let $\tilde{w} = w(\tilde{x})$ be welfare function (5) evaluated at the consumption choice $\tilde{x}$ that maximizes utility function (2), giving the indirect utility $\tilde{u} = u(\tilde{x})$ in Eq. (4). It is immediate to see that the welfare measure $\tilde{w}$ and the indirect utility $\tilde{u}$ are linked as follows:

$$\tilde{w}(t, z) = \tilde{u}(t, z) - (1 - \beta(z))\delta\gamma\tilde{x}(t, z). \tag{6}$$

Hence, the welfare measure is obtained by subtracting from the indirect utility the component of health harm, $(1 - \beta)\delta\gamma\tilde{x}$, that the smoker does not internalize in her consumption decisions because of lack of self- control.

4.2. Social welfare

We consider a continuum of heterogeneous consumer types, each one characterized by the set $\Pi = \{\rho, \gamma, \delta, \mathbf{b}\}$ of individual attributes. Let $F(.)$ be the cumulative distribution of types in the support set of the parameters and denote with $\mathrm{E}[\pi]$ the expected value of the parameter π, with π element of Π.

To define aggregate welfare, we adopt the utilitarian criterion by first adding up the individual welfare levels $\tilde{w}$, defined in Eq. (6), to obtain the aggregate measure $\mathrm{E}[\tilde{w}]$ (as the mass of the population is normalized to one, the average value for the entire population is equal to the aggregate value) and then by accounting for aggregate net public revenues, which are equal to the revenues from tobacco taxation, $\mathrm{E}[t\tilde{x}]$, less the expenditure z on anti-smoking campaigns, i.e.[15]

$$\tilde{T}(t, z) = \mathrm{E}[t\tilde{x}(t, z)] - z. \tag{7}$$

Assuming that the latter are distributed to consumers by means of lump sum transfers, our comprehensive measure of social welfare is given by

$$\tilde{\Omega}(t, z) = \mathrm{E}[\tilde{w}] + \tilde{T}. \tag{8}$$

Note that, since the individual utility function is quasi-linear, the marginal utility of income is constant and equal to one for all consumers, and therefore there are no income effects on tobacco demand. This, combined with the utilitarian criterion used to define social welfare, entails that we can sum the net public revenues $\tilde{T}$ to aggregate consumers' welfare $\mathrm{E}[\tilde{w}]$ without

[14] Quasi-hyperbolic discounting implies that the marginal rate of substitution between two temporally subsequent welfare outcomes, both occurring *in the future*, is equal to the discount factor δ, while that between a current and a one-period-forward outcome is equal to $\beta\delta$. Hence, when $\beta < 1$, the individual assigns a greater weight to current than to future outcomes.

[15] As it is standard in the literature on optimal taxation, we assume that there are no costs for tax administration.

loss of generality. In fact, social welfare as defined in Eq. (8) is invariant with respect to the actual distribution of net revenues among consumers through lump sum transfers.[16] In terms of our normative analysis, this implies that the objective function (8) accounts only for the social welfare benefits and costs of policy intervention in terms of efficiency. Indeed, distributional issues among heterogeneous individuals are outside the scope of the paper.

4.3. Efficient regulation of tobacco consumption

We characterize the efficient structure of tobacco regulation by considering a policy maker that sets the policy instruments (t, z) with the aim of maximizing the social welfare function defined in Eq. (8). By applying the implicit function theorem to the first order condition (3), we immediately obtain that both policy instruments have a negative impact on tobacco consumption, i.e.

$$\tilde{x}_t = 1/\tilde{v}_{xx} < 0, \;\; \tilde{x}_z = \beta_z \delta\gamma \tilde{x}_t \leq 0. \tag{9}$$

Eq. (9) also shows that the impact of prevention programs on tobacco consumption is proportional, by the factor $\beta_z \delta\gamma$, to that of taxation. This means that the behavioral responses in terms of tobacco consumption triggered by the policy instrument z are more diversified than those triggered by taxation, as the term $\beta_z \delta\gamma$ may be different for distinct types of smokers. Note that anti-smoking campaign programs determine more intense behavioral responses by smokers that suffer higher health costs γ due to smoking and that respond more to additional information on the hazards of smoking, as expressed by high values of β_z.

By differentiating Eq. (8) with respect to the policy instruments, we obtain

$$\tilde{\Omega}_t = \mathrm{E}[\tilde{u}_t - (1-\beta)\delta\gamma\tilde{x}_t] + t\mathrm{E}[\tilde{x}_t] + \mathrm{E}[\tilde{x}], \tag{10}$$

$$\tilde{\Omega}_z = \mathrm{E}[\tilde{u}_z - (1-\beta)\delta\gamma\tilde{x}_z + \beta_z\delta\gamma\tilde{x}] + t\mathrm{E}[\tilde{x}_z] - 1. \tag{11}$$

Using the envelope theorem, we have that $\tilde{u}_t = -\tilde{x}$ and $\tilde{u}_z = -\beta_z\delta\gamma\tilde{x}$, so that Eqs. (10) and (11) can be rewritten as

$$\tilde{\Omega}_t = -\mathrm{E}[(1-\beta)\delta\gamma\tilde{x}_t] + t\mathrm{E}[\tilde{x}_t], \tag{12}$$

$$\tilde{\Omega}_z = -\mathrm{E}[(1-\beta)\delta\gamma\tilde{x}_z] + t\mathrm{E}[\tilde{x}_z] - 1. \tag{13}$$

In both derivatives (12) and (13), the first term on the right-hand side represents the marginal benefits ensuing from the reductions in the internal costs of smoking that stem from the increase of the corresponding policy instrument, while the second term captures the marginal excess burden, expressed as the part of consumers' surplus reduction that is not rebated to individuals through the distribution of tax revenues. Finally, the third term of the derivative (13) is the marginal cost of government spending for anti-smoking campaigns.

Eqs. (12) and (13) can be used to characterize the optimal structure of tobacco control policy. Consider first the optimal level of tobacco taxation, for given expenditure on anti-smoking campaigns. Formally, by using the covariance decomposition to rewrite the first addendum on the right-hand side of Eq. (12), setting $\tilde{\Omega}_t = 0$, and rearranging terms, we obtain that, for given expenditure z in anti-smoking campaigns, the optimal tax rate $t^*(z)$ solves

[16] For the same reasons, in Section 3.2, we ignore in the consumer's budget constraint the lump sum transfer paid by the government.

$$t = \mathrm{E}[(1-\beta)\delta\gamma](1+\tilde{B}_t), \text{ where } \tilde{B}_t = \frac{\mathrm{cov}[(1-\beta)\delta\gamma, \tilde{x}_t]}{\mathrm{E}[(1-\beta)\delta\gamma]\mathrm{E}[\tilde{x}_t]}. \tag{14}$$

Although Eq. (14) does not provide an explicit expression for the optimal tax rate, it highlights how taxation corrects for the inefficiencies stemming from the internal costs of smoking. The first component of the optimal tax rate ($\mathrm{E}[(1-\beta)\delta\gamma]$) is the population-average marginal-internality — i.e., the average value of future health costs per unit of tobacco consumption that smokers fail to internalize into their consumption decisions because of lack of self-control. This term is scaled up or down by the factor $\tilde{B}_t$, the sign of which depends on the correlation between the individual marginal internal costs $(1-\beta)\delta\gamma$ and the individual responses $\tilde{x}_t$ of tobacco consumption to the tax-induced increase in the price of tobacco. If the covariance between $(1-\beta)\delta\gamma$ and $\tilde{x}_t$ is negative, then taxation is more effective at discouraging smoking among individuals characterized by high rather than low internal costs.[17] Similar arguments (with opposite signs) hold if the covariance is positive. In principle, first-best taxation would require an array of personalized tax rates tailored to the size of individual internalities $(1-\beta)\delta\gamma$. However, since such personalized taxes are unfeasible, a uniform tax $\mathrm{E}[(1-\beta)\delta\gamma]$ is applied, which means that a higher (respectively, lower) tax rate would be desirable for smokers with above-average (respectively, below-average) internal costs. Note that such uniform tax would be (second best) optimal only in the special case in which the smokers' behavioral responses to the tax-induced increases in the price of tobacco were uniform, i.e., if $\tilde{B}_t = 0$. Instead, if the behavioral responses are heterogenous, optimality requires to adjust the tax rate towards the internality levels of those smokers who are more responsive to taxation.[18]

Eq. (14) also sheds light on the direct relationship between taxation and spending in anti-smoking campaigns, showing that an increase in spending on anti-smoking campaigns z, by lowering β, lowers the optimal tax rate.[19]

The next step in the analysis of policy intervention is to ask to what extent, in the presence of an optimal tobacco tax, there is a role also for anti-smoking campaigns. Standard algebra (see Appendix A.2) shows that Eq. (13) can be rewritten, for $t = t^*(z)$, as

$$\tilde{\Omega}^*_z = -1 - \mathrm{E}[(1-\beta)\delta\gamma]\mathrm{E}[\tilde{x}^*_z](\tilde{B}^*_z - \tilde{B}^*_t), \tag{15}$$

where $\tilde{B}^*_z$ is defined as in Eq. (14) with $\tilde{x}^*_t$ replaced by $\tilde{x}^*_z$, and all variables that depend on $t^*(z)$ (defined by Eq. (14)) are indicated with the superscript *. The minus one on the right-hand side of Eq. (15) is the direct welfare cost of an additional dollar of public spending z on anti-smoking campaigns. Additional spending is thus socially worth if it brings about additional welfare benefits of at least the same value, as represented by the internalities in the second term of the equation. Notably, this term depends on the wedge between the scaling factors associated to the policy instruments z and t.

Recall that $\tilde{B}^*_z$ (resp. $\tilde{B}^*_t$) accounts for the degree of correlation between $\tilde{x}^*_z$ (resp. $\tilde{x}^*_t$) and $(1-\beta)\delta\gamma$, i.e. for the degree of correlation between the behavioral responses to policy

[17] Indeed, in this case, it is $\tilde{B}_t > 0$ ($\tilde{B}_t$ is positive if the covariance is negative, since $\mathrm{E}[\tilde{x}_t]$ is negative), so that the term $1+\tilde{B}_t$ scales up $\mathrm{E}[(1-\beta)\delta\gamma]$.

[18] The sign of the scaling factor $\tilde{B}_t$ is clearly an empirical matter. Lacking available evidence, we refer to our numerical examples in Section 5, pointing to a significant negative correlation between $(1-\beta)\delta\gamma$ and $\tilde{x}_t$.

[19] The statement highlights only the *direct* effect of policy instrument z on the efficient tax rate. As implied by Eq. (14), there are also (second order) indirect effects originating from the impact of z on tobacco demand functions.

instruments and the marginal internal costs of tobacco consumption. Hence, if $\tilde{B}_z^*$ and $\tilde{B}_t^*$ are both positive, then anti-smoking campaigns bring about additional welfare benefits (on top of those already reaped through taxation) only if $\tilde{B}_z^* > \tilde{B}_t^* > 0$ — i.e. if the degree of (negative) correlation of $(1-\beta)\delta\gamma$ with $\tilde{x}_z^*$ exceeds that with $\tilde{x}_t^*$. Instead, if $\tilde{B}_z^*$ and $\tilde{B}_t^*$ are both negative, then anti-smoking campaigns are useful only if $\tilde{B}_t^* < \tilde{B}_z^* < 0$, which means that the degree of (positive) correlation of $(1-\beta)\delta\gamma$ with $\tilde{x}_z^*$ is weaker than that with $\tilde{x}_t^*$.

Note that, under general conditions, the term $\tilde{B}_z^* - \tilde{B}_t^*$ in Eq. (15) is greater than zero, implying that anti-smoking campaigns are indeed a useful instrument to regulate tobacco consumption even if an optimal tax is already employed. To see why, focus on the special case in which all taste parameters are mutually uncorrelated and the consumers' utility function $v(.)$ is quadratic. Under these assumptions, one can see that $\tilde{B}_t^* = 0$ and (see Appendix A.2)

$$\tilde{B}_z^* = \frac{\mathrm{cov}[(1-\beta)\beta_z]}{\mathrm{E}[1-\beta]\mathrm{E}[\beta_z]} + \frac{\mathrm{var}[\delta\gamma]}{\mathrm{E}[\delta\gamma]^2} + \frac{\mathrm{cov}[(1-\beta)\beta_z]\mathrm{var}[\delta\gamma]}{\mathrm{E}[1-\beta]\mathrm{E}[\beta_z]\mathrm{E}[\delta\gamma]^2} > 0. \tag{16}$$

This special case highlights that the two policy instruments have complementary roles in correcting for excessive tobacco consumption due to lack of self-control by smokers. In particular, the optimal tax rate is parameterized on the marginal internal costs $\mathrm{E}[(1-\beta)\delta\gamma]$ of the 'average' smoker. If $(1-\beta)\delta\gamma$ and $\tilde{x}_t^*$ are uncorrelated, so that the scaling factor $\tilde{B}_t$ in Eq. (14) is nil, this is the only role that taxation can play. Anti-smoking campaigns are then useful since they determine behavioral responses that are more diversified than those caused by taxation. Given that $\tilde{x}_z^* = \beta_z \delta\gamma \tilde{x}_t^*$, prevention programs are more effective than taxation at discouraging smoking by individuals with large health costs and low degrees of self-control (provided that β_z is negatively correlated with β). The benefits of increased spending on anti-smoking campaigns are larger the larger is the variance of $\delta\gamma$ and the covariance between $(1-\beta)$ and β_z. Indeed, smokers do suffer different health damages γ from tobacco use, besides having different intertemporal preferences (i.e., different discount factors δ). Furthermore, the more self-controlled an individual is (i.e., the lower is $1-\beta$) the smaller the impact β_z of prevention programs on her degree of self-control should be.

Summarizing, the main insight emerging from the above discussion is that anti-smoking campaigns can usefully complement taxation in reducing the internal costs of smoking, as they are more effective than taxation at discouraging tobacco use by smokers characterized by low degrees of self-control and high smoke related health harms.

5. From theory to policy

In this section, we calibrate our theoretical model to empirical data to obtain additional insights about the optimal structure of policy intervention. Indeed, a more general characterization of the role of prevention programs, in the presence of correlation among taste parameters and with more general utility functions, can only be done by means of numerical methods.

5.1. Functional forms

As in O'Donoghue and Rabin (2006),[20] we consider a Constant Relative Risk Aversion (CRRA) specification of the utility of tobacco consumption; i.e.

$$v(x;\boldsymbol{\rho}) = \frac{\varrho}{1-\sigma}x^{1-\sigma}, \tag{17}$$

where $\boldsymbol{\rho} = (\varrho, \sigma)$, $\varrho > 0$ and $\sigma \in (0,1)$ are taste parameters. The corresponding demand function $\tilde{x}$ is given by

$$\tilde{x} = \left(\frac{\varrho}{1+t+\beta\gamma}\right)^{1/\sigma}. \tag{18}$$

Note that the demand function (18) is increasing in ϱ and decreasing in t and $\beta\gamma$, while the price elasticity is decreasing in σ and $\beta\gamma$, and increasing in t. The function $\beta(.)$, linking the expenditure z on prevention programs to the individual degree of self-control, takes the form

$$\beta(z;\mathbf{b}) = \kappa + \theta(1-\kappa)\frac{\mu\bar{\zeta}z}{1+\mu\bar{\zeta}z}, \ \mathbf{b} = (\kappa, \theta, \mu\bar{\zeta}). \tag{19}$$

This function is increasing and concave in z, and shaped by three taste parameters. $\kappa \in [0,1]$ represents the baseline level of β; i.e., the consumer's degree of self-control in the absence of prevention programs. $\theta \in [0,1]$ determines, jointly with κ, the asymptotic value of β when z goes to infinity, equal to $\kappa + \theta(1-\kappa)$, representing the maximum degree of self-control that the individual can achieve in the presence of anti-smoking campaigns.[21] $\mu \geq 0$ determines how sensitive the smoker is to the information conveyed by the campaign, since the function $\beta(.)$ is such that $\beta^J \geq \beta^K$ for all $z > 0$ whenever one considers two individuals J and K with the same κ and θ but $\mu^J \geq \mu^K$. Finally, the scalar $\bar{\zeta} \geq 0$ scales-up/down the taste parameter μ by a common factor for all smokers.

5.2. Calibration

Our model, except for the expenditure z on prevention programs impacting on β, is equivalent to O'Donoghue and Rabin (2006), and we replicate one of their numerical examples to start with.

The population is composed of identical individuals but for the baseline self-control parameter, which takes four uniformly distributed values $\kappa = \{0.9, 0.95, 0.99, 1\}$.[22] All other parameters are single valued. In particular, $\gamma = 10$, $\delta = 1$ (as it does not play any crucial role in our numerical analysis, we set to one the discount factor throughout), $\varrho = 17.7$, and $\sigma = 0.19$. The value of σ is

[20] Our numerical analysis extends that of O'Donoghue and Rabin (2006) who consider taxation as the only policy instrument.

[21] In the given specification $\lim_{z\to\infty}\beta(.)$ never exceeds one. That is, we assume that smokers never 'overreact' to the information transmitted through anti-smoking campaigns by consuming an amount of tobacco that is lower than the efficient level for a fully rational agent. Notwithstanding, our main qualitative results carry through even if we allow for over-reaction to anti-smoking campaigns.

[22] As noted by O'Donoghue and Rabin (2006), values of κ ranging from 0.9 to 1 reflect a population with mild self-control problems. Hence, if it turns out that taxation is a useful mean to improve social welfare in this context, it means that the case for its use is quite robust.

such that, for $\gamma = 10$, the elasticity of the aggregate demand of tobacco is equal to 0.5 for $t = 0$, while the value of ϱ is such that the aggregate demand is equal to 15 for $t = 0$.[23] The calibration of the health cost of smoking at 10 times the producer cost of tobacco is taken from Gruber and Kőszegi (2004). The value of 0.5 for the elasticity of tobacco demand is the value around which many empirical estimates are clustered; see the recent survey in U.S. National Cancer Institute and World Health Organization (2016, Ch. 4).[24] As for the parameters specific to our model, we specialize the function $\beta(.)$ in Eq. (19) by setting $\theta = 0.75$, implying that individuals with $\kappa = \{0.9,0.95,0.99,1\}$ have asymptotic values $\beta = \{0.975,0.9875,0.9975,1\}$, respectively, for $z \to \infty$. Moreover, since there is no empirical evidence helping to calibrate the impact of prevention programs on smokers' degree of self-control, we compute the optimal policy for various values of $\mu\bar{\zeta}$, by setting $\mu = 1$ and letting the scale parameter $\bar{\zeta}$ change.

5.3. The structure of optimal regulation policies

The results of our numerical simulations are in Table 2. The first row shows that, for $\bar{\zeta} \leq 1.416$, it is optimal to employ only the tax instrument, since anti-smoking campaigns are not enough effective at increasing smokers' degree of self-control and therefore are not worth their cost. In formal terms, for $\bar{\zeta} \leq 1.416$, it is $\tilde{\Omega}_z^* \leq 0$ for all $z \geq 0$, with $\tilde{\Omega}_z^*$ defined in Eq. (15). The reason is that — as shown in Column 2 — the derivative β_z evaluated at $z = 0$ ($\mathrm{E}[\beta_z^0]$) is too small. As in O'Donoghue and Rabin (2006), Table 2, fourth row, with no anti-smoking campaigns the optimal tax rate is $t^* = 49.2\%$.[25] Using Eq. (14), it is possible to split the value of the optimal tax rate into two components (not explicitly shown in Table 2). A first term, equal to 40%, reflects the average internal costs of smoking $\mathrm{E}[(1 - \beta^*)\delta\gamma]$. A second term, equal to the remaining 9.2%, reflects the fact that taxation is relatively more effective at discouraging smoking among the less than among the more self-controlled individuals. In fact, the term $\mathrm{cov}[(1 - \beta^*)\delta\gamma, \tilde{x}_t^*]/\mathrm{E}[\tilde{x}_t^*]$ in Eq. (14) is positive since both the numerator and the denominator are negative.

For $\bar{\zeta} > 1.416$, we depart from O'Donoghue and Rabin (2006), showing that it is optimal to employ both instruments. In Table 2 we consider eight values of $\bar{\zeta}$ that are multiples of the 1.416 threshold. Column 2 shows how increasing the scalar $\bar{\zeta}$, by increasing the value of $\mathrm{E}[\beta_z^0]$, affects the sensitivity of smokers to prevention programs. Columns 3–4, reporting the optimal policy (t^*, z^*), show that anti-smoking campaigns crowd out taxation: as $\bar{\zeta}$ increases from its lowest value of 1.416 to its maximum value of 1416, t^* falls from 49.2% to 12.5%, an effect almost entirely due to the positive impact of z^* on the average degree of self-control $\mathrm{E}[\beta^*]$,

[23] The optimal policy is independent of the scale of consumption, which is determined by the parameter ϱ. The chosen value of $\varrho = 17.7$ is such that aggregate demand (over the four κ types) equals 15, a figure that is purely evocative of an average per capita consumption of 15 cigarettes per day.

[24] In their numerical examples, O'Donoghue and Rabin (2006) consider also non-uniform distributions of the four values of κ and a value of one for the elasticity of aggregate demand. We consider only a uniform distribution of κ, since our interest lies in assessing the impact on tobacco regulation of other dimensions of smokers' heterogeneity, such as the variability in health costs (not considered by O'Donoghue & Rabin, 2006) and in the behavioral responses to anti-smoking campaigns, which are the original features of our analysis.

[25] Recall that, although the tax is of the specific type, its monetary value also expresses the tax in ad valorem terms, since the producer price of tobacco is equal to one, exogenously given. Note also that we denote with an asterisk both the optimal values of the policy instruments and the equilibrium values of variables that are functions of policy instrument.

Table 2
Effectiveness of anti-smoking campaigns and the optimal policy mix.

(1)	(2)	(3) (%)	(4)	(5) (%)	(6)	(7) % reduction in tobacco use (†) by individuals with $\kappa=$					(12) % reduction in welfare (†) by individuals with $\kappa=$				
$\bar{\zeta}$	$E[\beta_z^0]$	t^*	z^*	z^*/T^*	$E[\beta^*]$	0.90	0.95	0.99	1.00	all	0.90	0.95	0.99	1.00	all
1.416	0.042	49.2	.000	0.00	.960	22.3	21.4	20.7	20.5	21.4	0.40	0.18	0.13	0.13	0.83
2.832	0.085	39.6	.102	2.17	.967	25.1	20.9	17.7	17.0	20.8	0.59	0.16	0.06	0.06	0.88
4.248	0.127	35.2	.118	2.81	.970	26.4	20.8	16.3	15.2	20.6	0.67	0.16	0.04	0.04	0.92
5.664	0.170	32.4	.118	3.06	.972	27.3	20.7	15.5	14.2	20.5	0.72	0.17	0.04	0.03	0.96
7.080	0.212	30.5	.115	3.17	.973	27.9	20.7	14.9	13.4	20.4	0.76	0.17	0.03	0.03	0.98
14.16	0.425	25.6	.097	3.16	.977	29.5	20.6	13.3	11.4	20.2	0.84	0.18	0.02	0.02	1.06
70.80	2.124	18.2	.050	2.28	.983	32.1	20.7	10.8	8.3	19.9	0.95	0.20	0.01	0.01	1.17
141.6	4.247	16.2	.036	1.83	.985	32.9	20.7	10.2	7.4	19.8	0.98	0.20	0.01	0.01	1.20
1416	42.47	12.5	.011	0.75	.988	34.3	20.9	8.9	5.8	19.8	1.02	0.21	0.01	0.01	1.25

(†) With respect to no policy intervention ($t = z = 0$).

shown in column 6, which raises from 0.96 to 0.988. As a function of $\bar{\zeta}$, the optimal expenditure on prevention programs follows an inverse U-shape pattern, both in absolute terms (z^*, column 4) and as a share of tax revenues (z^*/T^*, column 5). Note that, for the central values of $\bar{\zeta}$ considered in the table, the ratio z^*/T^* is quite stable around 2–3% points.[26]

Overall, these results show that it is optimal to combine taxation and prevention policies to regulate tobacco consumption rather than relying on a single instrument only. The only exception is when the impact of prevention programs on smokers' degree of self-control is small, in which case they are not worth their cost. Interestingly, there is a crowding out effect of anti-smoking campaigns on taxation, with the optimal tax rate drastically falling as the impact of these campaigns on the average degree of smokers' self-control increases.

Columns 7–11 of Table 2 show how the optimal policy affects the tobacco consumption of individuals with different degrees of self-control. There are two factors at work. Taxation has a larger impact on those smokers that have lower degrees of self-control, since $\tilde{x}_t < 0$ is weakly increasing in β, while anti-smoking campaigns have a significantly larger impact in the same direction, since $\tilde{x}_z = \beta_z \delta\gamma\tilde{x}_t < 0$, with β_z decreasing in κ. Hence, if only taxation is used to regulate tobacco because anti-smoking campaigns are not implemented (as in the first row of Table 2), then the percentage reduction in smoking is about the same across types (from 22.3% for $\kappa = 0.9$ to 20.5% for $\kappa = 1$). If, instead, it is efficient to use both instruments, then the combination of a lower tax and a positive expenditure on prevention programs exerts a significantly different impact on the consumption of smokers with different degrees of self-control. For instance, focusing on the last row of Table 2, the percentage reduction of smoking is 34.3% for types $\kappa = 0.9$ and 5.8% for types $\kappa = 1$.

The last five columns of Table 2 show how tobacco regulation affects the welfare of different types of smokers.[27] Taxation affects smokers' welfare both through the induced reduction of

[26] These figures are in line with those reported by the Centers for Disease Control and Prevention (2012), according to which, over the period 1998–2010, the ratio of state tobacco revenues to state and federal tobacco control appropriations was approximately 30–1.

[27] The level of the individual welfare measure depends on the exogenous income I (see Eq. (5)). Hence, Table 2 reports the welfare changes in absolute terms — that are independent of I — rather than in percentage terms.

tobacco consumption and through the uniform distribution of tax revenues in the form of a lump sum subsidy. The two effects, however, are different for different types of smokers. On the one hand, more self-controlled smokers suffer a welfare loss since taxation distorts their otherwise efficient consumption choices. On the other hand, they benefit because (being below average smokers) the lump sum subsidy they receive is larger than the tobacco taxes they pay. Conversely, less self-controlled smokers experience a welfare gain, since taxation discourages excessive smoking, at the same time suffering, however, a welfare cost because (being above average smokers) the subsidy they cash is smaller than the taxes they pay. The nice feature of the optimal policy is that — despite these trade-offs — the welfare gain outweighs the welfare loss for all types of individuals. This is shown in the first row of columns 12–15 of Table 2, where the overall welfare change induced by the optimal tax is positive for all types of smokers. Rows 2–9 of columns 12–15 show that the implementation of a tobacco control policy determines a Pareto improvement also when it is optimal to use both policy instruments. However, as anti-smoking campaign programs become more effective, the welfare gains for the less self-controlled smokers get larger (Table 2, columns 12–13), while those for the more self-controlled smokers get smaller (columns 14–15). This is due to the crowding out effect of anti-smoking campaigns on taxation: the tax instrument, impacting almost uniformly on all types, is substituted by a prevention policy that is more effective in targeting the less self-controlled individuals.[28]

Note that the results reported in Table 2 are, in qualitative terms, robust to different model specifications and parameterizations. For instance, we show that our qualitative results carry over when considering different distributions of κ, when allowing 'low' values of κ to fit situations in which smokers not only lack self-control but also underestimate health harms, and when considering a linear relationship between β and z, as well as a linear demand for tobacco.

5.4. Other sources of consumers' heterogeneity

In Table 3 we examine how smokers' heterogeneity impacts on the structure of the optimal policy. We extend the analysis of Table 2, where the only source of heterogeneity is due to the parameter κ expressing the baseline degree of self-control, by allowing for heterogeneity also in γ, ϱ, θ, and μ. In particular, we consider three possible values of γ, $\gamma = \{5,10,15\}$, each one paired with two values of ϱ, so that there are two types of smokers for each value of γ: with low and with high tobacco demand. Specifically, $\gamma = 5$ is associated with $\varrho = \{10.1,14.8\}$, $\gamma = 10$ with $\varrho = \{16.4,18.7\}$, and $\gamma = 15$ with $\varrho = \{21.8,23.4\}$. This implies that the aggregate demand of tobacco evaluated at $t = z = 0$ is equal to 5 or 15 for low health cost types ($\gamma = 5$), to 10 or 20 for types with $\gamma = 10$, and to 15 or 25 for types with $\gamma = 15$. That is, there is a positive correlation between γ and ϱ to reflect the natural observation that, ceteris paribus, smokers with higher health costs are usually those that also consume more tobacco. For each one of the six subgroups (γ, ϱ), we set the parameter σ such that, after aggregating over κ, the elasticity of demand evaluated at $t = z = 0$ is equal to 0.5. Finally, for the remaining parameters, heterogeneity is introduced by allowing for two values of θ, $\theta = \{0.6,0.9\}$, and two values of μ,

[28] In the specification of Table 2, tobacco regulation determines a Pareto improvement because the only source of smokers' heterogeneity is their degree of self-control κ. With additional sources of heterogeneity, Pareto improvements are in general unfeasible, although O'Donoghue and Rabin (2006) define conditions for taxation to determine quasi-Pareto improvements.

Table 3
Smokers' heterogeneity and the optimal policy mix.

	variability in	(1) $\bar{\zeta}$	(2) $E[\beta_z^0]$	(3) % t^*	(4) z^*	(5) % z^*/T^*	(6) $E[\beta^*]$	(7) $\Delta\%$ (†) $E[x^*]$
(1a)	κ, ϱ	1.416	0.042	49.2	0.000	0.00	0.960	– 21.4
(1b)	κ, ϱ, γ	1.416	0.042	48.8	0.136	2.43	0.965	– 23.7
(1c)	κ, ϱ, θ	1.416	0.042	49.2	0.000	0.00	0.960	– 21.4
(1d)	κ, ϱ, μ	1.416	0.042	49.2	0.000	0.00	0.960	– 21.4
(1e)	κ, ϱ, γ, θ, μ	1.416	0.042	50.9	0.102	1.75	0.964	– 23.9
(2a)	κ, ϱ	4.248	0.127	35.2	0.118	2.81	0.970	– 20.6
(2b)	κ, ϱ, γ	4.248	0.127	35.1	0.183	4.51	0.973	– 22.8
(2c)	κ, ϱ, θ	4.248	0.127	35.6	0.113	2.67	0.970	– 20.6
(2d)	κ, ϱ, μ	4.248	0.127	37.5	0.099	2.23	0.968	– 20.7
(2e)	κ, ϱ, γ, θ, μ	4.248	0.127	38.1	0.163	3.69	0.971	– 23.0
(3a)	κ, ϱ	14.16	0.425	25.6	0.097	3.16	0.977	– 20.2
(3b)	κ, ϱ, γ	14.16	0.425	25.8	0.128	4.25	0.979	– 22.3
(3c)	κ, ϱ, θ	14.16	0.425	26.2	0.092	2.94	0.977	– 20.2
(3d)	κ, ϱ, μ	14.16	0.425	27.1	0.099	3.05	0.976	– 20.3
(3e)	κ, ϱ, γ, θ, μ	14.16	0.425	27.9	0.131	4.03	0.978	– 22.5

(†) With respect to no policy intervention ($t = z = 0$).

$\mu = \{0.5,1.5\}$. All parameters are uniformly and independently distributed (apart from γ and ϱ). When heterogeneity is not allowed along a specific dimension, the corresponding parameter is set at the value used in Table 2 ($\gamma = 10$, $\varrho = 17.7$, $\theta = 0.75$, $\mu = 1$). Finally, for all parameters but for ϱ, variability is introduced as a mean preserving spread; variability for ϱ is set to obtain a mean preserving spread in tobacco demand evaluated at $t = z = 0$.

Columns 3–4 of Table 3 report the optimal policy (t^*, z^*) for three of the $\bar{\zeta}$ values considered in Table 2, under various dimensions of smokers' heterogeneity. Adding variability in ϱ to that in κ shows that the optimal policy is unaffected: the values in rows 1a, 2a and 3a of Table 3 are the same reported in the corresponding entries of Table 2. The formal proof that the optimal tax rate is independent of the distribution of ϱ (with γ single valued) has already been provided by O'Donoghue and Rabin (2006). Our numerical analysis shows that this result also applies to the case of two policy instruments (tax and prevention programs). Novel results are obtained when introducing heterogeneity in γ, θ, and μ. In particular, allowing for variability in γ, makes the marginal benefits of prevention programs larger (as already noted in Section 4.3 when discussing Eq. (16)), thus determining a substantial increase in z^* while having a negligible impact on t^*.[29] In this perspective, our numerical analysis confirms the insights gained in Section 4.3, namely that the additional contribution of anti-smoking campaigns (with respect to the usage of taxes alone) depends on the degree of smokers' heterogeneity. This holds true also when

[29] The comparison of rows 1a and 1b of Table 3 shows that, for $\bar{\zeta} = 1.416$, we have $z^* = 0$ with variability in (κ, ρ), and $z^* = 0.118$ with variability in (κ, ρ, γ). For $\bar{\zeta} = 4.248$ and for $\bar{\zeta} = 14.16$, the introduction of variability in γ determines an increase in the optimal expenditure on prevention programs by 56% and 32%, respectively.

allowing for heterogeneity in θ or μ, although the implications in terms of optimal policy are less clear-cut. Adding variability in θ to that in κ and ϱ reduces, ceteris paribus, the optimal expenditure z^*, with no significant impact on t^* (see rows 1c, 2c and 3c of Table 3). The addition of variability in μ has, instead, a non monotonic effect on z^*, while still having a negligible impact on t^*.[30]

Overall, the insights of the numerical analysis in Table 3 suggest that, for a given characterization of the representative smoker, changes in the degree of smokers' heterogeneity have only a negligible effect on the optimal tax rate, but a significant impact on the optimal expenditure on anti-smoking campaigns. In particular, a larger variability in the value of the health harm related to smoking turns out to increase the marginal benefits of prevention programs.

6. Concluding remarks

We examine the optimal design of policies controlling tobacco consumption through the joint use of two instruments — excise taxation and anti-smoking mass media campaigns — in a setting in which smokers are heterogeneous in terms of the intensity of preferences for smoking, the health costs suffered from tobacco consumption, and the degree of self-control. We find that anti-smoking campaigns can usefully complement taxation in controlling tobacco consumption. While the optimal tax mainly corrects for the population-average internal costs of smoking, anti-smoking campaigns induce behavioral responses by smokers that are more diversified than those induced by taxation both between smokers with low and high degrees of self-control and between smokers suffering low and high health costs. In particular, anti-smoking campaigns contribute to social welfare by reducing excessive tobacco consumption by the less self-controlled smokers and by those that suffer larger health costs due to smoking.

Our analysis can be extended along several dimensions. While our framework combines two major policy instruments for controlling tobacco consumption, additional more specific measures could be considered, such as smoking bans in public places, or regulatory policies that target specific groups of individuals, like youth access laws. Cremer et al. (2012) examine how the optimal structure of sin taxes is affected by the possibility that some individuals — realizing that their past sin-goods consumption has been a mistake — decide to buy health care coverage to insure against future health harms. This type of setting could be usefully combined with ours, by allowing prevention programs to influence or trigger the choice of investing in health care. Additionally, our setting could be extended to explicitly deal with the social aspects of smoking — i.e., the fact that smoking habits may ensue from imitation and social interactions or cultural factors (see, e.g., Nyborg & Rege, 2003, Cutler & Glaeser, 2010, Sari, 2013, and Christopoulou & Lillard, 2015).

In our framework, as in most of the literature on sin goods (e.g., Gruber & Kőszegi, 2004 and O'Donoghue & Rabin, 2006), the market for tobacco is assumed to be perfectly competitive. In terms of our normative analysis, introducing imperfect competition does not greatly affect the results. Market power simply implies that the optimal tax rate shown in Eq. (14) contains an additional negative term, expressing a subsidy component to correct for the fact that firms price

[30] For $\overline{\zeta} = 4.248$, adding variability in μ reduces z^* by 15%, while for $\overline{\zeta} = 14.16$ it increases z^* by 2%. We conjecture that these results depend on the fact that *general* anti-smoking mass media campaigns represent an imperfect instrument when the behavioral responses of smokers are highly heterogeneous. In this case, it is likely that an array of *specific* campaigns, each one targeted to a different but homogeneous group (e.g., the youth, middle-aged males or females, and so on), could do better than a general campaign.

above marginal costs. Instead, imperfect competition can be important in a positive perspective, since tobacco corporations spend a large amount of resources to lobby policy makers to lessen tobacco regulation policies and to finance information campaigns aimed at counteracting public prevention programs, leading to a political economic analysis of tobacco regulation.[31]

The presence of imperfect competition also paves the way for the investigation of the effects on consumers' welfare and firms' profits of the introduction of restrictions on the advertising of sin goods (like tobacco) as a further regulatory instrument. Since persuasive advertising is conceived to inflate consumers' demand, regulating it is likely to improve social welfare with respect to what can be achieved by relying on taxation only.

Appendixes

A.1. The WHO indicators

As described at https://www.who.int/initiatives/mpower, in 2008 the World Health Organization introduced the MPOWER package to assist in the country level implementation of six effective measures to reduce demand for tobacco products. Each measure reflects at least one provision of the WHO Framework Convention on Tobacco Control. Two of these measures, or policy instruments, are the ones on which we focus in our theoretical analysis: taxation and anti-smoking media campaigns (the other four measures in the MPOWER package are: smoking bans, monitoring tobacco use, enforcement of bans on tobacco advertising, promotion, and sponsorship, offer help to quit tobacco use).

We next report the Metadata Registry provided by the WHO for the indicators represented in Figures 1a and 1b of Section 2, and in Table A.1 of this Appendix.

A.1.1. Tobacco taxation

(http://apps.who.int/gho/data/node.wrapper.imr?x-id=374).

Country provided information on taxes and prices is assessed to yield indicators that describe the comparative level of taxes on tobacco products in countries. Taxes assessed include excise tax, value added tax (VAT), import duty (when cigarettes are imported) and any other taxes levied. Only the price of the most popular brand of cigarettes is considered. In the case of countries where different levels of taxes applied to cigarettes are based on either length, quantity produced or type (e.g., filter vs. nonfilter), only the rate that applies to the most popular brand is used in the calculation. Given the lack of information on country and brand specific profit margins of retailers and wholesalers, their profits are assumed to be zero (unless provided by the national data collector). The implementation status of the Raise tobacco taxes measure is classified by grouping countries into five groups. The groupings for this indicator are: 1= Data not reported; $2 = 0 - 25\%$ of retail price is tax; $3 = 26 - 50\%$ of retail price is tax; $4 = 51 - 75\%$ of retail price is tax; $5 =$ more than 75% of retail price is tax.

Data available at https://apps.who.int/gho/data/node.main.TOBMPOWER?lang=en and https://apps.who.int/gho/data/node.main.TOBNATTAX?lang=en (Last updated: 2020–07–20).

[31] In the USA, over the period 2004–2011, the contributions to candidates and committees at the Federal, State, and local levels by lobbyists representing the interests of the tobacco industry totaled $145,750,000, a sum corresponding to 7.1% of excise tax revenues at the Federal, State and local levels over the same period.

A.1.2. Anti-tobacco mass media campaigns

(http://apps.who.int/gho/data/node.wrapper.imr?x-id=2723).

The implementation status of the Antitobacco mass media measure is classified by assigning countries to five groups. The groups for this indicator are: 1 = Data not reported; 2 = No national campaign conducted in the reporting period with a duration of at least three weeks; 3 = National campaign conducted with 1–4 appropriate characteristics* ; 4 = National campaign conducted with 5–6 appropriate characteristics* , or with 7 characteristics excluding airing on TV and/or radio; 5 = National campaign conducted with at least 7 appropriate characteristics* including airing on TV and/or radio.

* Characteristics of a high quality campaign are: the campaign is part of a tobacco control program; before the campaign, research has been undertaken or reviewed to gain a thorough understanding of the target audience; campaign communications materials have been pretested with the target audience and refined in line with campaign objectives; air time (radio, television) and/or placement (billboards, print advertising, etc.) is obtained by purchasing or securing it using either the organization's own internal resources or an external media planner or agency (this information indicates whether the campaign adopted a thorough media planning and buying process to effectively and efficiently reach its target audience); the implementing agency works with journalists to gain publicity or news coverage for the campaign; process evaluation is undertaken to assess how effectively the campaign has been implemented; an outcome evaluation process is implemented to assess the campaign impact.

Data available at https://apps.who.int/gho/data/node.main.TOBMPOWER?lang=en (Last updated: 2020–05–28).

A.2. Optimality conditions

A.2.1. Anti-smoking campaigns: derivation of Eq. (15)

Using the covariance decomposition to expand the first term on the right-hand side of Eq. (13), we obtain

$$\tilde{\Omega}_z = -\mathrm{cov}[(1-\beta)\delta\gamma, \tilde{x}_z] + \mathrm{E}[t-(1-\beta)\delta\gamma]\mathrm{E}[\tilde{x}_z] - 1. \tag{A.1}$$

Setting $\tilde{\Omega}_t = 0$, with $\tilde{\Omega}_t$ defined in Eq. (12), and solving for t, we get the optimal tax rate $t^*(z)$, which is implicitly defined by the following equation

$$t^* = \mathrm{E}[(1-\beta)\delta\gamma] + \frac{\mathrm{cov}[(1-\beta)\delta\gamma, \tilde{x}_t^*]}{\mathrm{E}[\tilde{x}_t^*]}. \tag{A.2}$$

Substituting for t^* from Eq. (A.2) into Eq. (A.1), and simplifying, we obtain

$$\tilde{\Omega}_z^* = -\mathrm{cov}[(1-\beta)\delta\gamma, \tilde{x}_z^*] + \frac{\mathrm{cov}[(1-\beta)\delta\gamma, \tilde{x}_t^*]}{\mathrm{E}[\tilde{x}_t^*]}\mathrm{E}[\tilde{x}_z^*] - 1,$$

which after further rearrangements can be rewritten as

$$\tilde{\Omega}_z^* = -E[\tilde{x}_z^*]\left\{\frac{\text{cov}[(1-\beta)\delta\gamma,\ \tilde{x}_z^*]}{E[\tilde{x}_z^*]} - \frac{\text{cov}[(1-\beta)\delta\gamma,\ \tilde{x}_t^*]}{E[\tilde{x}_t^*]}\right\} - 1, \tag{A.3}$$

so that we finally obtain Eq. (15) in the main text.

A.2.2. Anti-smoking campaigns: derivation of Eq. (16)

Substituting $\tilde{x}_z^* = \beta_z \delta\gamma \tilde{x}_t^*$ from Eq. (9) into $\tilde{B}_z^*$, we obtain

$$\tilde{B}_z^* = \frac{\text{cov}[(1-\beta)\delta\gamma,\ \beta_z\delta\gamma\tilde{x}_t^*]}{\text{E}[(1-\beta)\delta\gamma]\text{E}[\beta_z\delta\gamma\tilde{x}_t^*]} = \frac{\text{E}[(1-\beta)\beta_z(\delta\gamma)^2\tilde{x}_t^*]}{\text{E}[(1-\beta)\delta\gamma]\text{E}[\beta_z\delta\gamma\tilde{x}_t^*]} - 1. \tag{A.4}$$

If all taste parameters are mutually uncorrelated and if the utility function is quadratic, then (δ, γ), (β, β_z), and $\tilde{x}_t^*$ are mutually uncorrelated. This implies that Eq. (A.4) can be written as

$$\tilde{B}_z^* = \frac{\text{E}[(1-\beta)\beta_z]\text{E}[(\delta\gamma)^2]}{\text{E}[1-\beta]\text{E}[\beta_z]\text{E}[\delta\gamma]^2} - 1. \tag{A.5}$$

By manipulating the numerator of the fraction in Eq. (A.5) using the covariance and the variance decomposition formulas, we get

$$\tilde{B}_z^* = \frac{\{\text{cov}[(1-\beta)\beta_z] + \text{E}[1-\beta]\text{E}[\beta_z]\}\{\text{var}[\delta\gamma] + \text{E}[\delta\gamma]^2\}}{\text{E}[1-\beta]\text{E}[\beta_z]\text{E}[\delta\gamma]^2} - 1. \tag{A.6}$$

Finally, by rearranging the terms in Eq. (A.6) as follows

$$\tilde{B}_z^* = \frac{\text{cov}[(1-\beta)\beta_z]\text{var}[\delta\gamma] + \text{cov}[(1-\beta)\beta_z]\text{E}[\delta\gamma]^2 + \text{E}[1-\beta]\text{E}[\beta_z]\text{var}[\delta\gamma]}{\text{E}[1-\beta]\text{E}[\beta_z]\text{E}[\delta\gamma]^2},$$

and simplifying, we obtain Eq. (16) in the main text.

Table A.1
(part I). Tobacco regulation indicators and tax rates (years 2010 and 2018).

Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate	Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate
Afghanistan	2	1	3.6	2	2	4.1	Cote d'Ivoire	3	3	25.3	3	4	33.3
Albania	4	5	52.9	4	2	67.2	Cabo Verde	2	2	9.7	2	4	11.2
Algeria	3	2	48.8	3	1	34.2	Cambodia	2	4	17.1	3	4	25.1
Andorra	4	1	58.0	5	2	79.3	Cameroon	2	2	18.7	2	1	21.3
Angola	1	2	dna	2	1	23.7	Canada	4	2	62.2	4	2	64.3
Antigua and Barbuda	2	1	14.8	2	2	13.3	Central African Republic	3	2	32.8	3	2	41.5
Argentina	4	4	69.3	5	3	76.2	Chad	2	2	24.8	3	4	34.1
Armenia	2	2	23.6	3	1	38.1	Chile	5	2	76.4	5	4	82.4
Australia	4	5	63.8	5	5	77.5	China	3	2	49.0	4	4	55.7
Austria	4	2	73.0	5	5	75.3	Colombia	3	5	49.9	5	1	78.4
Azerbaijan	2	2	20.5	3	4	35.3	Comoros	4	2	51.3	3	2	37.3
Bahamas	3	2	31.2	1	2	dna	Congo	3	2	32.2	3	2	37.1
Bahrain	3	4	28.6	4	3	64.5	Cook Islands	3	2	46.3	4	2	70.3
Bangladesh	3	2	48.0	4	4	71.0	Costa Rica	3	2	41.6	4	5	55.1
Barbados	3	5	47.8	3	2	47.1	Croatia	4	2	71.7	5	2	78.8
Belarus	3	2	28.2	4	5	50.9	Cuba	1	5	dna	4	1	70.2
Belgium	5	2	76.3	5	2	77.0	Cyprus	4	1	72.1	4	5	74.4
Belize	4	2	59.2	3	2	43.6	Czechia	5	4	78.6	5	4	75.4
Benin	2	2	12.0	2	2	4.9	Democratic People's Republic of Korea	1	1	dna	2	1	0.0
Bhutan	na	5	na	na	2	na	Democratic Republic of the Congo	3	1	28.5	3	2	38.7
Bolivia (Plurinational State of)	3	2	37.7	3	4	36.8	Denmark	4	5	74.8	4	4	74.1
Bosnia and Herzegovina	4	2	72.2	5	2	83.8	Djibouti	3	2	25.5	1	2	dna
Botswana	4	4	55.4	3	3	49.9	Dominica	3	1	25.6	2	4	23.6
Brazil	4	3	59.4	5	5	83.0	Dominican Republic	4	2	57.1	4	2	51.1
Brunei Darussalam	na	4	53.6	na	5	na	Ecuador	4	2	64.3	4	2	70.0
Bulgaria	5	2	88.7	5	2	83.6	Egypt	4	5	73.8	5	2	77.2
Burkina Faso	3	2	32.2	3	2	41.6	El Salvador	4	4	54.8	3	5	47.5

(*continued on next page*)

Table A.1 (*continued*)

Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate	Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate
Burundi	4	2	56.3	3	2	42.8	Equatorial Guinea	2	2	22.0	3	1	25.3
Eritrea	4	4	55.4	4	2	55.4	Italy	5	4	75.2	5	5	76.0
Estonia	5	1	82.6	5	5	79.4	Jamaica	4	2	51.2	3	1	43.6
Eswatini	3	2	44.8	4	2	52.7	Japan	4	2	63.1	4	3	63.1
Ethiopia	3	2	39.2	2	4	18.8	Jordan	5	4	79.6	5	5	80.5
Fiji	1	2	dna	3	5	42.1	Kazakhstan	3	5	26.7	4	1	52.4
Finland	5	5	78.8	5	3	87.4	Kenya	4	2	63.8	4	2	52.3
France	5	3	80.4	5	5	82.4	Kiribati	4	2	62.5	3	2	41.7
Gabon	2	1	19.6	2	2	23.1	Kuwait	3	4	36.0	2	2	21.2
Gambia	4	2	56.1	3	4	46.3	Kyrgyzstan	3	2	25.5	3	2	48.6
Georgia	3	4	48.6	4	5	71.2	Lao People's Democratic Republic	2	2	14.1	2	1	18.8
Germany	4	5	74.1	4	5	68.3	Latvia	5	2	81.5	5	2	80.0
Ghana	2	2	22.2	3	4	31.3	Lebanon	3	5	47.4	3	3	45.6
Greece	5	5	85.7	5	2	81.2	Lesotho	3	2	45.0	4	4	50.9
Grenada	3	2	49.5	3	2	44.0	Liberia	2	2	19.4	3	2	34.8
Guatemala	4	2	51.8	3	1	49.0	Libya	2	2	23.0	2	2	12.6
Guinea	2	4	13.1	1	2	dna	Lithuania	5	2	77.1	4	2	73.8
Guinea-Bissau	2	2	5.6	2	2	6.8	Luxembourg	4	1	70.1	4	5	68.3
Guyana	3	2	25.2	3	2	27.5	Madagascar	5	5	76.3	5	2	80.4
Haiti	1	1	dna	1	2	dna	Malawi	1	2	dna	1	2	dna
Honduras	3	4	39.0	3	4	33.4	Malaysia	4	5	52.3	4	1	58.6
Hungary	5	3	78.9	4	2	72.3	Maldives	3	2	31.6	4	2	68.7
Iceland	4	2	56.4	4	2	55.5	Mali	2	2	21.8	3	2	27.7
India	3	5	45.2	4	4	54.0	Malta	5	4	76.3	5	1	77.6
Indonesia	4	2	54.1	4	5	58.5	Marshall Islands	3	2	49.5	4	1	54.1
Iran (Islamic Republic of)	2	1	2.7	2	3	21.7	Mauritania	2	1	6.9	2	2	9.6
Iraq	2	2	1.3	2	5	7.6	Mauritius	4	2	71.7	5	2	83.5
Ireland	5	5	78.5	5	5	78.4	Mexico	4	2	62.7	4	1	67.0
Israel	4	4	72.3	5	2	75.9	Micronesia (Federated States of)	4	2	66.7	3	2	48.6

(*continued on next page*)

Table A.1 (*continued*)

Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate	Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate
Monaco	1	1	dna	1	1	dna	Qatar	3	2	33.3	3	5	40.0
Mongolia	3	5	49.7	3	1	47.4	Republic of Korea	4	1	62.0	4	5	73.8
Montenegro	4	2	64.9	5	2	81.4	Republic of Moldova	3	3	30.1	4	5	58.0
Morocco	4	5	66.4	4	4	71.2	Romania	5	4	83.2	4	2	68.6
Mozambique	3	2	26.5	3	2	28.5	Russian Federation	3	5	35.0	4	2	57.7
Myanmar	3	3	25.0	3	5	32.5	Rwanda	3	5	37.9	4	3	55.9
Namibia	3	2	46.2	3	4	44.1	Saint Kitts and Nevis	2	2	14.0	2	2	19.8
Nauru	3	1	42.3	3	1	48.3	Saint Lucia	3	2	26.5	4	5	51.2
Nepal	3	4	28.7	3	1	30.0	Saint Vincent and the Grenadines	2	1	14.7	2	2	16.9
Netherlands	4	5	73.0	4	4	71.8	Samoa	4	5	61.3	3	3	49.5
New Zealand	5	4	80.3	5	5	82.2	San Marino	4	1	74.2	1	2	dna
Nicaragua	3	2	29.1	3	2	40.2	Sao Tome and Principe	3	2	25.0	3	2	40.4
Niger	3	5	29.6	3	2	31.3	Saudi Arabia	3	3	28.6	4	4	68.1
Nigeria	2	2	20.6	3	2	29.7	Senegal	3	2	30.3	3	5	38.2
Niue	4	4	62.8	5	2	87.7	Serbia	5	4	75.1	5	2	77.3
North Macedonia	4	1	72.1	5	2	81.3	Seychelles	4	3	67.6	4	5	70.1
Norway	4	2	72.3	4	5	64.0	Sierra Leone	2	2	13.5	2	2	18.6
occupied Palestinian territory, including east Jerusalem	5	2	77.7	5	4	83.5	Singapore	4	5	67.2	4	4	67.1
Oman	3	2	30.8	3	2	25.0	Slovakia	5	2	83.3	5	2	77.1
Pakistan	4	2	55.0	4	5	56.4	Slovenia	5	2	75.9	5	3	79.2
Palau	4	2	57.1	4	4	73.0	Solomon Islands	1	1	dna	3	2	34.1
Panama	4	2	59.2	4	5	56.5	Somalia	2	1	10.0	2	2	4.5
Papua New Guinea	1	2	dna	4	2	54.2	South Africa	3	2	48.3	4	2	54.6
Paraguay	2	2	15.5	2	2	17.4	South Sudan	1	4	dna	1	2	dna
Peru	3	2	47.1	3	1	49.0	Spain	5	2	78.3	5	2	78.2
Philippines	3	5	28.4	4	4	71.3	Sri Lanka	4	4	73.9	4	1	66.2
Poland	5	5	86.4	5	2	76.8	Sudan	4	4	67.7	4	2	69.8

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Table A.1 (*continued*)

Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate	Country	2010 i_tax	2010 i_amc	2010 t_rate	2018 i_tax	2018 i_amc	2018 t_rate
Portugal	5	2	79.0	4	3	71.7	Suriname	3	2	49.9	3	2	47.6
Sweden	4	5	71.6	4	2	68.4	Ukraine	4	2	70.2	4	3	74.7
Switzerland	4	5	63.5	4	5	60.3	United Arab Emirates	3	4	28.6	4	2	73.5
Syrian Arab Republic	3	1	33.0	3	2	41.8	United Kingdom of Great Britain and Northern Ireland	5	5	76.7	5	5	79.4
Tajikistan	3	2	29.9	3	2	42.3	United Republic of Tanzania	3	2	26.1	3	2	32.1
Thailand	4	4	68.7	5	4	78.6	United States of America	3	2	45.3	3	5	43.0
Timor-Leste	1	1	dna	2	5	21.8	Uruguay	4	4	72.3	4	1	66.1
Togo	2	5	21.7	2	5	22.0	Uzbekistan	3	2	29.7	3	2	44.7
Tonga	4	2	56.3	4	5	62.4	Vanuatu	4	1	55.5	4	2	58.6
Trinidad and Tobago	3	1	33.7	3	2	25.7	Venezuela (Bolivarian Republic of)	4	5	71.0	4	2	73.0
Tunisia	5	4	86.0	4	3	72.0	Viet Nam	3	5	31.8	3	5	36.7
Turkey	5	5	78.3	5	5	81.4	Yemen	4	3	53.5	4	3	50.6
Turkmenistan	4	1	57.6	3	5	32.4	Zambia	3	5	36.3	3	2	41.2
Tuvalu	2	2	15.8	3	2	29.5	Zimbabwe	4	2	51.7	3	2	35.9
Uganda	3	2	44.6	3	4	39.9							

Legend: i_tax: taxation indicator; i_amc: antismoking mass media campaigns indicator; t_rate: total tax rate; na: not applicable; dna: data not available
Source: WHO, Global Health Observatory (see data description in Appendix A.1)

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