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SIN GOODS TAXATION: AN ENCOMPASSING MODEL

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Abstract

We analyse optimal sin taxes. After identifying the distinctive features of sin goods, we develop a simple, encompassing framework that allows to treat the main models found in the literature as subcases. We derive the optimal sin tax rates, also considering the subsidisation of healthy goods. We then discuss the Pareto-improvement result obtained in the theoretical literature, confronting it with the debate on the regressivity of this kind of taxation. We highlight the crucial role of the interaction of tastes, self-control problems and poverty when deriving policy conclusions from theoretical models.

JEL classification codes: H21; H22; D11.

Keywords: Sin goods; Optimal taxation; Tax burden; Consumer sovereignty.

OPTIMAL TAXATION OF SIN GOODS: AN ANALYTICAL REVIEW

1. Introduction

The increase in the global burden of non-communicable diseases (cardiovascular and coronary heart diseases, diabetes, some types of cancer) has stressed the role of diet and prevention (World Health Organization, 2016). Thus, excessive consumption of unhealthy commodities, such as food and beverages that are rich in salt, fat and sugar, has been added to traditional vices, such as the abuse of alcohol, tobacco, drugs, gambling, the so called sin goods (Alcott et al., 2019a; Hines, 2007), renewing old questions on the scope for government intervention to discourage their consumption. Sin goods share with merit goods (Musgrave, 1957, 1958; Scitovski, 1992) the contrast to certain community preferences, in that health is now being given an increasing social value. There is, however, a feature that distinguishes sin goods from demerit goods: overconsumption of sin goods is a mistake also from the individual point of view, in that it is regretted afterwards by consumers themselves (see, for instance, Cremer et al., 2012). This is because people do not (fully) take into account the damage to their own health deriving from the consumption decision.

Making an error is thus equivalent to imposing an externality upon oneself, often referred to as an internality (Herrnstein et al., 1993). Public intervention thus overcomes a difficulty in implementing consumer sovereignty, rather than treading upon it. This feature also distinguishes the category of sin goods from that of externalities (even if their consumption is often associated to costly external effects: on the externalities stemming from sin goods consumption see, among others, Manning et al., 1989; Crawford et al., 2010). The mistake is typically ascribed to self-control problems, deriving from time inconsistency because of myopia, that is, a short term propensity that individuals regret afterwards (O'Donoghue and Rabin, 2006), or emotional factors, such as a transitory feeling of deprivation (Hoch and Loewenstein, 1991) or a perceived wedge between self-interest and behaviour because of the operation of visceral factors (Loewenstein, 1996) turned on by cues (Laibson, 2001; Bernheim and Rangel, 2004). Overconsumption can be targeted by fiscal policy, typically by changing the relative price of sin goods via taxation. In the last years, for instance, a wide debate has accompanied the introduction of new taxes on unhealthy items, such as sugary drinks, saturated fats, confectionery, chocolate, ice creams. In 2019, 75 countries had a tax on sugar-sweetened beverages (Table 1) – they were 53 in 2019[1]. In France, they amounted to 1,67% of total consumption tax revenues in 2018 (Table 2).

Table 1. Sugar-Sweetened Beveradge Taxes around the World (2019)

Low Income countries	***Lower Middle income countries***	***Upper Middle Income countries***	***High Income countries***
Benin	*Bangladesh*	*Argentina*	*Bahrain*
Burundi	*Bolivia*	*Belize*	*Barbados*
Chad	*Côte d'Ivoire*	*Brazil*	*Belgium*
Ethiopia	*El Salvador*	*Costa Rica*	*Brunei*
Gambia	*Honduras*	*Dominica*	*Chile*
Liberia	*India*	*Ecuador*	*Cook Islands*
Mali	*Kenya*	*Fiji*	*Estonia*
Niger	*Mauritania*	*Guatemala*	*Finland*
Togo	*Micronesia*	*Iran*	*France*
Uganda	*Morocco*	*Malaysia*	*Hungary*
Tanzania	*Nicaragua*	*Mauritius*	*Ireland*
	Nigeria	*Mexico*	*Latvia*
	Philippines	*Montenegro*	*Monaco*
	São Tomé and Principe	*Paraguay*	*Norway*
	Senegal	*Perù*	*Oman*
	Tunisia	*St. Vincent and the Grenadines*	*Panama*
	Vanuatu	*Samoa*	*Portugal*
	Zambia	*South Africa*	*St. Kitts and Nevis*
		Sri Lanka	*Saudi Arabia*
		Suriname	*Seychelles*
		Thailand	*Spain*
		Tonga	*United Arab Emirates*
			United Kingdom
			Uruguay

Source: World Health Organization

[1] Data available from https://www.who.int/data/gho/data/indicators/indicator-details/GHO/existence-of-tax-on-sugar-sweetened-beverages.

https://www.who.int/data/gho/data/indicators/indicator-details/GHO/existence-of-tax-on-sugar-sweetened-beverages
In Spain sugar tax was introduced in Catalonia

Table 2. Tax revenue from sugar tax in Europe (2018)

	Sugar tax revenue (mln national currency)	*% of total consumption tax revenue*
Belgium	*174,6*	*0,34*
Finland	*155*	*0,60*
France	*4600*	*1,67*
Hungary	*40727*	*0,60*
Ireland	*16,93*	*0,07*
Norway	*3149*	*0,78*
Portugal	*74,52*	*0,26*
Spain	*7*	*0,01*
United Kingdom	*237*	*0,10*

Source: National Tax List-Eurostat. For Spain: 2017 data. In Europe the "sugar tax" is variously called: Belgium: import duties and excises on non-alcoholic beverages; Finland: 1) sugar levy; 2) excises duties on sweets, ice cream and soft drink; Hungary: Public health product tax (introduced in 2011. It is a tax levied on food products containing unhealthy levels of sugar, salt and other ingredients harmful for health); Portugal: import duties and excises on beverages with added sugar or others sweeteners; France: Taxes on beverages (It applies to all non-alcoholic beverages containing added sugar or sweeteners); Norway: 1) tax on non-alcoholic beverages; 2) sugar tax; Spain: sugar isoglucose levies; Ireland: sugar tax; UK: soft drink industry levy.

This class of taxes, as well as the traditional ones on alcohol and tobacco (Crawford et al., 2010), are, however, often criticised, both as expression of paternalism in government intervention and because of their regressive impact. Within this framework, the literature provides different perspectives of analysis from several disciplines for the sin goods. A branch of literature analyses the effects of the sin goods on the behaviour of firms and consumers. For firms, the literature highlights the effects of social norms on marketing strategies (Cahan et al., 2017; Christensen and Nafzigerb, 2016; Craig Smith and Cooper-Martin, 1997; Davidson, 2002, 2003; Grougiou et al., 2016; Harrison and Kacperczyk, 2009; Kang et al., 2016; Kim and Venkatachalam, 2011; Kotler and Levy, 1971; Prevel Katsanis, 1994).

Another set of contributions mainly focuses on consumers' behaviour stressing psychological elements (Strotz 1955-56; Pollack 1968; O' Donoghue and Rabin 1999, 2001). By identifying different types of consumers according to the weight given to various elements – such as rationality, addiction, emotional factors, self-control and commitment – this literature defines different levels of paternalistic public intervention as cautious paternalism (O' Donoghue and Rabin, 1999c), asymmetric paternalism (Camerer et al., 2003) and libertarian paternalism (Thaler and Sunstein, 2003). These analyses basically suggest that moderate public intervention policies significantly affect consumers with self-control problems, while having little effect on the others.

A complementary branch of the economic literature analyses the instruments of public intervention. Most of the analyses concern the optimal taxation of sin goods, while less attention is given to public policies – as education and diffusion of information – designed to make consumers more aware of the damages from sin goods consumption on health. The theory of sin goods taxation is based on a variety of models that differ from each other in the analytical form of the utility function, which in turn reflects the consumers' preferences and attitudes towards sin goods (see references in Table 3).

Against this background, this paper presents an analytical review of the theoretical economic literature on the taxation of sin goods. This is done using a simple, encompassing model, that allows to treat the main models found in the literature as subcases (section 2); we then discuss the efficiency and distributive effects of sin taxes; section 4 concludes the paper.

Table 3. Sin goods taxation: a quick reference list.

Hyperbolic discounting

O'Donoghue, T., and M. Rabin (1999b); Carrillo, J.D. (1999); O'Donoghue, T., and M. Rabin (2003); O'Donoghue, T., and M. Rabin (2006); Camerer, C., S. Issacharoff, G. Loewenstein, T. O'Donoghue, and M. Rabin (2001); Haavio, M., and Kotakorpi, K. (2011); Cremer, H., De Donder, Ph., Maldonado, D., and Pestieau, P. (2012); Immordino, G., Menichini, A.M., and Romano, M.G. (2015); Haavio, M., and Kotakorpi, K. (2016).

With addiction

Gruber, J., and B. Koszegi (2001; Gruber, J., and B. Koszegi (2004); Gruber, J. (2010).

Visceral influences

Loewenstein, G. (1996); Loewenstein, G. (2000).

Cues and addiction

Laibson, D. (2001); Bernheim, B.D. and Rangel A. (2004).

Cues and temptation

Gul F., and W. Pesendorf (2001).

Reference-point models

Hoch, S.J., and G.F. Loewenstein (1991).

Health investment and subsidisation

Yaniv, G., O. Rosin, and Y. Tobil (2009); Cremer, H., De Donder, Ph., Maldonado, D., and Pestieau, P. (2012); Wang J, L. Marsiliani, and T. Renstrom (2017); Cheng, C.-C., and H. Chu (2017).

2. The theoretical framework for the taxation of sin goods: an encompassing model

2.1 An overview

Mainstream economics takes consumer sovereignty as the reference point of welfare evaluation. Thus, if well-informed individuals choose their consumption levels of the sin goods rationally, a corrective public intervention can be justified only if consumption exerts externalities on others. Actually, excise taxes on tobacco and alcohol have traditionally been justified on this ground. Crawford et al. (2010) review the estimates of the amount of externalities generated by the consumption of these two products, finding that it is quite low for smoking, while it is quite high for drinking. Despite this, at least in developed countries, excise taxes are quite higher than the corresponding externality estimates for tobacco, while the opposite is true for excise taxes on alcohol. This divergence has been interpreted as an indication of the inadequacy of standard utility models in explaining the choice of consuming – and taxing - sin goods, given their typically addictive nature and the relevant negative effects of consumption on consumers' health.

A good is potentially addictive if increases in past consumption raise current consumption (complementarity between future and present consumption, as in learning-by-doing set-ups). Some addictive goods have a negative impact on future utility (and earnings). The shadow price of the addictive good is thus equal to the sum of its market price and the money value of these future costs. Individuals might recognise these detrimental effects and still rationally choose to consume an addictive good if the resulting increase in utility is higher than the related cost (Becker and Murphy, 1988). Addiction is thus rational in the sense that there is forward-looking maximisation with stable preference, i.e., individuals maximise utility consistently over time.

The effect of past consumption on the utility of current consumption implies that tastes are no longer fixed. This is the core of the idea of *habit formation* proposed by Duesenberry (1952). Habit formation does not contrast with rationality if individuals can correctly predict the effect of current consumption on future tastes. But are people able to do it? Experimental evidence, starting with Loewenstein and Adler (1995), seems to contradict this. And, even if individuals were able to correctly optimise their utility function, would they be able to carry out their plans? For this second aspect, too, there is some contrary laboratory evidence (Ainlie and Haslam, 1992).

On these premises, the literature has developed alternative models, that share a common feature: the existence of self-control problems, that, at the theoretical level, stem from deviations from the standard discounted utility model, dating back to Samuelson (1937). One can divide these models into two broad categories. The first one identifies the mistake in the time inconsistency of individual behaviour. In these models, the discount function is assumed to be non-exponential, which implies time-inconsistent preferences. In particular, hyperbolic discounting is assumed, with a declining rate of time preference. As a consequence, once future periods are reached, people will make choices that are more impatient than what is preferred according to to-day's tastes. The second category, instead, considers deviations from the standard model that consist in additional elements of the instantaneous utility function. In particular, these allow either for fluctuations in tastes due to visceral influences/cues, or for reference-dependent utility. The effect is an increase in the utility of immediate consumption of the sin good. In connection with visceral cues, there are also models that allow for an effect on utility from not chosen alternatives (temptation utility), which represent a more radical departure from the standard discounted utility model. The role of all these factors is more relevant in the case of habit formation, even if not dependent on addiction itself.

To discuss this literature, we adopt a simple, encompassing model, that allows for both hyperbolic discounting and increased utility of current sin good consumption because of transitory emotional factors or a bias in the prediction of tastes. Parameters modifying the utility and cost of the sin good represent deviations from the standard utility model.

2.2 A basic encompassing model

Let us first consider the behaviour of a single (representative) consumer. In the standard intertemporal utility maximization framework, individuals discount the future exponentially, that is, if *d* is the one –period discount factor, they discount *n* periods forward at a rate of d^n:

$U^t(u_t, \ldots, u_T) \equiv u_t + \sum_{s=t+1}^{T} d^{s-t} u_s,$

where *u* is the instantaneous utility function.

The first deviation we allow for is the introduction of a second parameter, *b*; a preference for immediate gratification is expressed by a value of $b < 1$, while $b = 1$ corresponds to the standard model:

$U^t(u_t, \ldots, u_T) \equiv u_t + b \sum_{s=t+1}^{T} d^{s-t} u_s.$

Thus, while the relative discount rate between two future periods is 1, that between today and tomorrow is less than 1, which implies impatience as for present consumption. This implies time inconsistency, that is, when the future actually arrives, the individual will consume more than what is considered optimal from to-day's point of view. For simplicity, we assume d=1 throughout the paper.

The second deviation from the standard model concerns the instantaneous utility function, in that we allow for the operation of an increase in today's utility from sin good consumption deriving from visceral factors; these are introduced by the parameter *e*; a value of e>0 might capture emotions triggered in by the operation of cues (assuming that the cue is operative in any period, we have e_s >1 if $t=s$, e_s=0, $t>s$).

The instantaneous utility function is assumed to be log-linear:

$u_t \equiv a(1+e)\ln(x_t) + gln(y_t) + z_t - cln(x_{t-1}), \; a \geq c.$

where *x* is a sin good, *y* a standard good, and *z* the numeraire. Consumption of the sin good does not only imply an increase in utility in the present, but also (health) costs in the future, that, for simplicity, occur only in the period following consumption. Benefits and costs of period *t* consumption are additively separable from consumption in any other period. Thus, in each period, the maximisation problem is:

$$\max u^{*}(x_t, y_t, z_t) \equiv a(1+e)\ln(x_t) + gln(y_t) + z_t - bcln(x_t) = (a(1+e) - bc)ln(x_t) + gln(y_t) + z_t \quad (1)$$

s.t. the individual budget constraint:

$$p_x x_t + p_y y_t + z_t = H \quad ,$$

where H is the individual endowment of the numeraire good.

Expenditure on x will be $a(1+e) - bc$, while expenditure on y will be g. Thus, individual demand will be:

$$x^{*} = \frac{(a(1+e) - bc}{p_x}$$
$$y^{*} = \frac{g}{p_y}$$
$$z^{*} = H - (a(1+e) - bc + g)$$

In the literature that we illustrate below, the two deviations from the standard model, that is, b<1 and e>0, are considered to be mistakes, deriving from self-control problems. Thus, individual choices differ from the optimal ones, derived from the following maximand:

$$u^{**}(x_t, y_t, z_t) \equiv (a-c)\ln(x_t) + gln(y_t) + z_t \, . \quad (2)$$

Optimal quantities demanded will then be:

$$x^{**} = \frac{a-c}{p_x}$$
$$y^{**} = \frac{g}{p_y}$$
$$z^{**} = H - (a - c + g) \, .$$

By comparing the levels of quantity demanded for the sin good, one can note that, if $e > 0$ and/or $b < 1$, $x^* > x^{**}$, that is, there is overconsumption of the sin good.

We now review the models that adopt a hyperbolic utility function, on the one hand, and those modifying the instantaneous utility function, on the other hand, as special cases of this encompassing framework.

3. The hyperbolic utility function

3.1 Case 1: e=0, b≤1

Let us consider the case in which the only deviation from the standard model is represented by a value of *b≤1*, with *e=0*. The parameter reflects a short-term propensity that the individual will regret thereafter. This is the standard model in this strand of the literature (see, in particular, O’Donoughe and Rabin, 2003, 2006). Equation (1) becomes:

$$\max u^*(x_t, y_t, z_t) \equiv a\ln(x_t) + gln(y_t) + z_t - bcln(x_t) = (a - \text{bc})\ln(x_t) + gln(y_t)\, z_t \quad (1’)$$

The parameter b, thus, induces an undervaluation of future costs associated to present consumption of the sin good. Quantities demanded become: [2]

$$x^* = \frac{a-bc}{p_x}$$
$$y^* = \frac{g}{p_y}$$
$$z^* = H - (a - bc + g).$$

The deviation from the standard model is thus intertemporal inconsistency. In a seminal paper on intertemporal inconsistency, Strotz (1955-56) considers exponential discounting just as a particular case of discounting. He argues that individuals reconsider plans as time goes on. Since the discount function is

[2] The demand for the sin good is elastic w.r.t. to the parameter b if $b > \frac{a}{2c}$.

shifted, the solutions of the utility maximisation problem can be different. Actually, there is only one case in which they remain the same, that is, if all future periods are discounted at a constant rate (exponential discounting). In other words, the relative importance of period *t* and period *t+1* is the same at *t-1* and *t*. In all other cases, individuals constantly repudiate their plans, since preferences in the future differ from to-day's preferences.

Strotz also raises a concern for discount functions that overvalue "the more proximate satisfaction relative to the more distant ones (p. 177)", especially if these are "gained at the expense of still-more-future cost (p. 179)". This applies, among other situations, to the consumption of sin goods.

Laibson (1997) explicitly considers a hyperbolic utility function, which displays a declining discount rate between time *t* and time *t+1*, but a constant discount rate thereafter. Declining discount rates are connected to self-control problems (Loewenstein and Prelec, 1992). O'Donoghue and Rabin (1999a, 2001) argue that present biased preferences implied by hyperbolic discounting produce procrastination of actions involving immediate costs and preproperation of actions involving immediate rewards. Individuals might be *sophisticated*, that is, aware of this self-control problem, or *naïve*, that is, they think that in the future they will have the same preferences as in the present.[3] Individuals willing to ensure that they will do tomorrow what is best from to-day's point of view can adopt a pre-commitment strategy, eliminating options that, though being inferior to-day, might be preferred in the future.

Hyperbolic preferences have been used to explain actual economic behaviour

[3] For laboratory evidence on sophistication and naiveté (and on 'dual selves') see Della Vigna, 2009.

in several types of decisions, beginning with consumption-saving choices. O'Donoghue and Rabin (1999b), Carrillo (1999) and Gruber and Koszegi (2001) have started a strand of the literature that applies it to the consumption of addictive goods. In particular, Gruber and Koszegi (2001, 2004) incorporate hyperbolic discounting into the Becker and Murphy (1988) model, with sophisticated individuals wishing to consume less in the future than what they will actually manage to do. Since people do not act in their best interest, consumer sovereignty is no longer an argument against government intervention if externalities are not present. In particular, they show that the discounted utility of a sophisticated consumer can rise with the imposition of a tax, since this works as a commitment device that agents cannot implement by themselves.

O'Donoghue and Rabin (2006) consider sin goods that are not addictive. Actually, the fundamental feature of addictive behaviour is the dependence of the utility of present consumption on the level of past consumption. This characteristic is not a necessary feature of a sin good. Its essential characteristic is overconsumption, regretted afterwards because of the consequent health costs. Hyperbolic preferences delver this feature, since they generate a short-term propensity that is regretted afterwards. Thus, individuals do not maximise their own welfare. The existence of such mistakes is a common issue in the behavioural economics literature (see, for instance, Kahneman, 1994). Once again, even in the lack of addiction, there is a role for taxation, that can be illustrated using our simplified model. Let us assume that the government maximises the individual's "long-run" utility (eq. 2). Thus, it considers time inconsistency an error, that it can correct through taxation. Let us consider two cases, a tax on the sin good only, that is returned to consumers by a lump sum subsidy, and a Ramsey optimal taxation framework. For simplicity, in what follows we normalise to unity pre-tax prices.

3.2 Sin taxation and lump sum subsidy

Let us consider the case of the government wishing to tax the sin good just to correct for the distortion in individual choice. It therefore maximises eq. (2) subject to the budget constraint:

$$S = t_x x^* \qquad (3)$$

where S is a lump sum subsidy, that returns the amount of the numeraire subtracted via taxation to the consumer. The tax distorts the price of the sin good, that becomes $p_x = (1 + t_x)$. The individual budget constraint is:

$$p_x x_t + \ p_y y_t + \ z_t = H + S.$$

Quantities demanded become:

$$x^* = \frac{a-bc}{(1+t_x)}$$
$$y^* = g$$
$$z^* = H + S - (a - bc + g).$$

The government maximises eq. (2) s.t. eq. (3). By substituting for quantities demanded, the maximand becomes:

$$W = (a - c)ln\frac{(a-bc)}{(1+t_x)} + gln(g) + H + S - (a - bc + g),$$

which, by substituting for S from (3), becomes:

$$= (a - c)ln\frac{1}{(1+t_x)} + t_x\left(\frac{a-bc}{(1+t_x)}\right) + (a - c)\ln(a - cb) + glng + H - (a - bc + g).$$

(2a)

Since $(a - c)\ln(a - cb) + glng + H - (a - bc + g)]$ is independent of taxes, the government chooses the tax rate to maximise:

$$(a - c)ln\frac{1}{(1+t_x)} + t_x\left(\frac{a-bc}{(1+t_x)}\right). \qquad (2a')$$

By differentiating w.r.t. t_x, one gets the expression for the optimal sin tax:

$t_x^* = \frac{c(1-b)}{a-c}$.

The rationale for the tax is a Pigouvian correction for the internality: with *b*=1, the optimal tax rate would be zero. The result can be extended to the case of heterogeneous individuals. For adherence to the real context, we consider a situation in which the government cannot make use of personalised taxes and transfers.[4] To concentrate on the role of intertemporal inconsistency, we assume that individuals differ only in the value of the parameter *b*, which is a random variable with support b∈ [0,1]. As a consequence, *b* induces a probability distribution on *x*: quantity demanded depends both on the price and on the individual value of the parameter *b*; therefore, $x = f(p_x, b)$, with support $x \in [0, \bar{x}]$. Let us assume that the policy maker maximises a utilitarian welfare function attaching an equal weight to each individual. Though maximising u**, with *b*=1, the parameter *b* enters the maximand since it affects *x*, the quantity demanded of the sin good.

To attach the same weight to all individuals, the maximand will be the expectation of individual welfare: $\max \int_0^1 [(a-c)lnx - p_x x + t_x x]db + glny + [H - p_y]$

$$W = \int_0^1 [(a-c)lnx - x - t_x x + t_x x]db + glny + [H - p_y]$$

$$W = \int_0^1 [(a-c)lnx - x]db + glny + [H - p_y] = E_b[U_x] + glny + [H - p_y]$$

Maximising w.r.t. p_x to obtain t_x^* (given that $p_x = 1 + t_x$; note that only the term $E_b[U_x]$ is involved) yields:

[4] If they were available, first-best efficiency could be achieved. The same result would obtain with alternative personalised instruments, in particular sin licenses (O'Donoghue and Rabin, 2003; Haavio and Kotakorpi, 2016).

$\frac{dU}{dp_x} = E_b\left[\left(\frac{a-c}{x^*} - 1\right)\frac{dx^*}{dp_x}\right] = 0$, if $(\frac{a-c}{x^*} - 1)$=0.

Substituting from the F.O.C. of the individual maximisation ($x^* = \frac{a-bc}{1+t_x}$), one gets:

$t_x^* = \frac{c}{a-c}E(1-b)$,

with $E(1\text{-}b)$ representing the average intertemporal distortion, which replaces the individual parameter value of the representative individual case. O'Donoughe and Rabin (2006) argue that, with uniform tax and transfers, taxation of the sin good distorts consumption choices and redistributes income from people that consume a greater amount of the sin good to people that consume a lower one. With taste heterogeneity, even in the lack of self-control problems, taxation only creates a second-order loss, while transfers create first-order effects from income redistribution. If some individuals have self-control problems, they benefit because taxes counteract overconsumption, while rational consumers receive income: a Pareto improvement is possible in this context.[5] These results hinge on the assumption that rational individuals consume less than irrational ones. However, if individuals differ both in the standard parameters (a, c, g) and in the error parameter b, deviations from b=1 cannot be detected on the basis of the amount consumed, unless in the $a = c$ case, with time consistent individuals not consuming the sin good at all.

Haavio and Kotakorpi (2011) analyse the determination of sin taxes under majority voting. With hyperbolic consumers, the equilibrium tax will generally be lower than the socially optimal level. This is because the median

[5] Immordino et al. (2015) extend the O'Donoghue and Rabin (2006) framework to the case of inefficient taxation. In our model, this case would correspond to a value of the lump-sum subsidy that falls short of revenues by the measure of the inefficiency parameter, that is: $S = \mu t_x x$, with $\mu<1$ representing the inefficiency parameter.

voter does not take into account that the positive welfare effect of taxation on hyperbolic consumers exceeds the negative impact on rational consumers. The result hinges upon the hypothesis that the demand of irrational consumers, characterised by a high consumption level, is more price-elastic than that of rational consumers, with a low consumption level.[6]

3.3 A Ramsey optimal taxation framework

In a Ramsey optimal taxation framework, the government maximises eq. (2) subject to the budget constraint:

$$R = t_x x^* + t_y y^* \tag{3a}$$

Taxes distort prices, that become

$$p_x = (1 + t_x)$$
$$p_y = (1 + t_y)$$

Quantities demanded become:

$$x^* = \frac{a-bc}{(1+t_x)}$$
$$y^* = \frac{g}{(1+t_y)}$$
$$z^* = H - (a - bc + g)$$

The government maximises (2) s.t. (3a), from which we derive optimal taxes. Substituting quantities demanded into equation (2) and (3a), the maximand becomes:

$$W = [(a-c)ln\frac{(a-bc)}{(1+t_x)} + gln\left(\frac{g}{1+t_y}\right) + H - (a - cb + g) = (a-c)ln\frac{1}{(1+t_x)} + gln\frac{1}{(1+t_y)} +$$

$$(a-c)\ln(a-cb) + glng + H - (a - bc + g)] \qquad (2b)$$

Since $(a-c)\ln(a-cb) + glng + H - (a - bc + g)]$ is independent of taxes, the government chooses tax rates to max

$$(a-c)ln\frac{1}{(1+t_x)} + gln\frac{1}{(1+t_y)} \qquad (2b')$$

[6] See section 4 for a discussion of this hypothesis.

s.t. $t_x \frac{(a-bc)}{(1+t_x)} + t_y \left(\frac{g}{1+t_y}\right) = R$ (3a')

Eq. (3a') implicitly defines a function $t_y(t_x)|_R$. Differentiating (3a') yields:

$$\frac{(a-bc)}{(1+t_x)^2} + t_y \frac{g}{(1+t_y)^2} \frac{dt_y}{dt_x}|_R = 0$$

$$\frac{dt_y}{dt_x}|_R = -\frac{a-bc}{g}\left(\frac{1+t_y}{1+t_x}\right)^2 \qquad (4)$$

Taking the FOC of (2b') w.r.t. t_x and using (4):

$$\frac{-(a-c)}{1+t_x} - \frac{g}{1+t_y}\frac{dt_y}{dt_x}|_R = \frac{-(a-c)}{1+t_x} + \frac{g}{1+t_y}\left(\frac{a-bc}{g}\left(\frac{1+t_y}{1+t_x}\right)^2\right) = 0$$

$$\frac{1+t_y}{1+t_x} = \frac{a-c}{a-bc} \qquad (5)$$

Using (5) and (3a') one gets:

$$t_x^* = \frac{R}{a-bc+g-R} + \frac{c(1-b)(\frac{g}{(a-c)})}{a-bc+g-R}$$

$$t_y^* = \frac{R}{a-bc+g-R} - \frac{c(1-b)}{a-bc+g-R}$$

If the individual were rational, that is, with $b=1$, the tax rates on the two goods would be the same, given that they have the same price elasticity; otherwise, the sin good is taxed more than the other good, since the government wishes to correct the consumer's mistake. If the government does not aim at raising revenues, that is, with $R=0$, we have that y is subsidized; thus, if y were a "healthy" good, taxing the sin good implies subsidizing the healthy one. In a framework with heterogeneous individuals, if the government cannot use personalised instruments, the above expressions hold with the parameter b replaced by its average value, as above. In such a context, O'Donoughe and Rabin (2003) argue that increasing taxes on unhealthy goods (and lowering taxes on healthy or neutral ones) has second order negative effects on rational consumers, but possibly high first order effects on irrational ones, given that they correct for overconsumption of the sin good.[7]

3.4 An extension: effects of investment in healthy activities

The negative effect on health not fully anticipated and regretted afterwards is the distinctive feature of sin goods. Thus, the literature has added investment in health to the basic framework of analysis. The role of investment in health has been studied, among others, by Grossman (1972), Goulao and Pérez-Barahona (2014). With more direct reference to the taxation of sin goods, Cremer et al. (2012) consider a two period framework in which individuals can, in the second period, invest in health care to counteract the negative effect of first-period sin good consumption. They distinguish between people with 'dual selves', who actually recognize their error in time to correct it by the choice of the amount of health expenditure, and people who do not (or not before having chosen the amount of health services consumption). Optimal tax rates depend on a Pigouvian, corrective component and a redistributive one. They find that, for both types of people, the sin tax is lower if wealthier individuals are less myopic. In the case of dual selves, the sin tax is higher and the health subsidy is lower, the higher their impact on savings.

Wang et al. (2017) suggest that taxes on sin goods might be ineffective in improving health if they also determine a decrease in investment in health. As a consequence, sin taxation should be accompanied by other instruments, such as subsidies on health investments or reductions in the income tax. To account for this issue, we consider an extension of the hyperbolic model, introducing

[7] For an analysis of the subsidization of healthy food subsidization, see Cheng and Chu (2017); Yaniv et al. (2009) find that a subsidy for healthy food might increase obesity (because preparing healthy food subtracts time to physical activities), while a tax on unhealthy food decreases it.

the opposite of a sin good, let us call it a healthy good. Its consumption not only increases current utility, but also exerts a positive effect with a one period lag. With a hyperbolic discount function, this positive effect will be undervalued as the negative one from sin good consumption. To consider this case, let us extend our basic model and consider y a healthy good. The instantaneous utility function becomes:

$u_t \equiv a\ln(x_t) + gln(y_t) + \ z_t - cln(x_{t-1}) + hln(y_{t-1});$

in each period the (representative) consumer maximises:

$$u^*(x_t, y_t, z_t) \equiv \ a\ln(x_t) + gln(y_t) + \ z_t - bcln(x_t) - bcln(y_t)$$
$$= (a - bc)ln(x_t) + (g + bh)ln(y_t) + \ z_t$$

while optimal behaviour (that is, b=1) would entail maximising:

$$u^{**}(x_t, y_t, z_t) \equiv (a - c)\ln(x_t) + (g + h)ln(y_t) + \ z_t \qquad (2')$$.

Quantities demanded will be:

$$x^* = \frac{(a - bc)}{p_x}$$
$$y^* = \frac{g + bh}{p_y}$$
$$z^* = H - (a - bc + g + bh)$$

that differ from those that would obtain under optimal behaviour:

$$x^{**} = \frac{a - c}{p_x}$$
$$y^{**} = \frac{g + h}{p_y}$$
$$z^{**} = H - (a - c + g + h).$$

In particular, myopia implies not only an overconsumption of the sin good as before, but also an under-consumption of the healthy one ($z^{**} > z^*$). We assume again that the government maximises (2') in a Ramsey optimal taxation framework. The budget constraint will thus again be equation (3a), which, after substituting in from the individual maximisation F.O.C.s, becomes:

$$t_x \frac{(a-bc)}{(1+t_x)} + t_y \left(\frac{g+bh}{1+t_y}\right) = R \qquad (3b)$$

Following the same procedure as before, we derive the optimal tax rates:

$$t_x^* = \frac{R}{a-bc+g+bh-R} + \frac{(1-b)(\frac{ah+cg}{(a-c)})}{a-bc+g+bh-R}$$

$$t_y^* = \frac{R}{a-bc+g+bh-R} - \frac{(1-b)(\frac{ah+cg}{(g+h)})}{a-bc+g+bh-R}$$

with the sin good being taxed and the healthy good subsidised. Assuming, for simplicity, $c=h$, the optimal tax rates become:

$$t_x^* = \frac{R}{a+g-R} + \frac{(1-b)(\frac{c(a+g)}{(a-c)})}{a+g-R}$$

$$t_y^* = \frac{R}{a+g-R} - \frac{(1-b)(\frac{c(a+g)}{(g+h)})}{a+g-R}.$$ [8]

3.5 Time inconsistency and government intervention: some reflections

The hyperbolic utility function appears appealing; beside the discount rate, it gives a higher weight to consumption in the only period in which we are certainly alive, that is, to-day. It also delivers the individual's regret that supports a corrective public intervention without impairing consumer's sovereignty. One can, however, argue that time inconsistency might be found with respect to consumption choices over some goods only. Actually, while the standard model considers one single discount rate, a large body of empirical literature shows that discount rates are inconsistent across different goods. Frederick et al. (2002) review this literature and argue that time preference should be studied through a composite approach, as it was in the economic literature of the early twentieth century.

But if the time inconsistency parameter *b* applies to some goods only, the same results could be obtained if the parameter *b* referred to a valuation of the future

[8] See the Appendix for the derivation of the optimal tax rates with heterogeneous individuals.

damage to health (or a value attached to health) that is lower than the ‘correct’ one rather than to myopic behaviour. With a standard intertemporal utility function:

$U^t (u_t, \ldots, u_T) \equiv u_t + \sum_{s=t+1}^{T} d^{s-t} u_s$

and an instantaneous utility function of the following form:

$u_t \equiv a \ln(x_t) + gln(y_t) + z_t - bcln(x_{t-1}),$

the individual maximand is expressed by equation (1’) as in the hyperbolic consumer case. Under this perspective, hyperbolic discounting and underestimation of future damages to health are equivalent, but regret for not sticking to plans is no longer a justification for government intervention. Government intervention is instead triggered in by a different evaluation of these damages, or, equivalently, a different evaluation of the value of health from the individual one. Which brings back to demerit goods arguments. The practical reference point for government intervention becomes quantity consumed, and therefore expected effects on health themselves, regardless of the extent of self-control problems. A different evaluation of marginal harm from consuming the sin good (higher for the government than for the individual) rather than a correction for time inconsistency is then the factor that triggers government intervention in.

4. Enriched specifications of the instantaneous utility function

Let us now consider the case in which the only deviation from the standard model is represented by a value of $e>0$, with $b=1$, which we call case 2. The parameter reflects an overvaluation of present consumption of the sin good that stems from transitory or unpredicted changes in tastes; this case of the model comprehends several approaches that deviates from the standard utility model as for the configuration of the instantaneous utility function. We divide them into two classes: a) models in which the short term propensity to consume is explained by *visceral* factors; b) habit formation (addiction) models with bias in the prediction of tastes.

4.1 Visceral factors.

An alternative to the explanation of time inconsistent behaviour provided by the hypothesis of hyperbolic discounting is a short-term increase in the propensity to consume the sin good brought about by visceral factors (see, for instance, Loewenstein, 2000). This terms refers to emotional influences such as craving, thirst, hunger, fear, pain. They can induce a transitory alteration in tastes, while the permanent evaluation of the good remains the same. Visceral influences differ from tastes under several respects (Loewenstein, 1996): they fall back on different neuropsychological mechanisms (chemical regulations, while tastes draw on information stored in memory); they change more rapidly than tastes; these changes are correlated with external circumstances; even if the consumption level remains constant, these changes have direct hedonic consequences (that are negative, in the examples mentioned above). Though visceral influences share with hyperbolic discounting the consumer's focusing on the present, they are not only turned on by the time factor, but also by other forms of "proximity" to the good, or cues (e.g., spatial proximity, smell, sounds, etc.). The operation of these different types of cues allows to confine inconsistent behaviour to some types of goods (and environmental circumstances) only, while hyperbolic discounting refers to all goods. Laibson (2001) and Bernheim and Rangel (2004) analyse the role of cues in addictive behaviour to provide a “biological micro-foundation” to the Becker and Murphy (1988) model. Laibson (2001) assumes that addiction effects are activated by the presence of cues associated with past consumption of the addicted good. Therefore, a current cue is complementary with current consumption if that cue has been associated with consumption in the past. The operation of visceral factors, however, introduces time inconsistency in behaviour, thus invalidating the rationality assumptions of the Becker and Murphy (1988) model. Again, it is possible to distinguish between sophisticated and naïve consumers. Laibson (2001) shows that those individuals who perceive a wedge between behaviour and self-interest will be willing to follow a ‘pseudo-commitment’ strategy, that is, to devote resources to reduce their future choice set. Thus, differently from consumers in the Becker and Murphy (1988) model, who find it optimal to remain addicted, given that the level of past consumption is given, consumers can manipulate cues and resist consumption. Moreover, if individuals are willing but unable to manage cues, public intervention can be beneficial (Bernheim and Rangel, 2004). Of course, attempts to resist consumption show that this is somehow unwanted: use is a mistake, that is, a pathological divergence between choice and preference. Another class of models that belong to the broader category of “visceral factors” are those with reference dependent utility (Tversky and Kahnemann, 1991; Hoch and Loewenstein, 1991). These models adopt the prospect theory (Kahneman and Tversky, 1979) assumption that outcomes are evaluated over a value function defined over departure from a reference point, which might depend, for instance, on past consumption. A shift in the reference point can bring about a sudden and transitory change in tastes. This induces a state of deprivation, that operates as a cue, increasing the 'long-run' utility by the relief from deprivation. Again, pre-commitment might be used to manipulate the reference point and resist overconsumption. All these models try to bridge the gap between rational and emotional motives, as in Holbrook et al. (1990); an attempt dating back to Abelson (1963) and Hirschmann (1977).[9]

4.2Habit formation (addiction) with bias in the prediction of tastes.

A value of $e>0$ can derive also from addiction; as exposed above, the basic feature of addiction is the increase in utility of the addictive good because of past consumption. ($e>0$ if $x_{t-1}>0$). This can be seen as a particular case of the endowment effect, that is, the tendency of people to value a good more highly once they possess it than they would do if they did not. There is nothing irrational in this change in tastes taken by itself, as addiction is not in the Becker and Murphy (1988) model. Some authors have, however, questioned whether people are able to foresee the effects of their current behaviour on their own future tastes (Thaler; 1990; Kahnemann et al., 1990; Loewenstein and Adler, 1995). Their experimental evidence indicates a downward bias in the prediction of the effects of the magnitude of the endowment effect.[10] Thus, (over)consuming to-day is again a mistake and this can be represent by the additional parameter e of our simple model. Addictive behaviour becomes irrational not because of the undervaluation of future costs, but because of the

[9] An alternative to preference changes is given by temptation utility models (Gul and Pesendorfer, 2001), that extend the utility function to include temptation, so that well-being depends also on alternatives that are actually not chosen. Temptation is an option that the agent would prefer not to have and that decreases utility either by distorting choice or requiring costly self-control. Thus, even if the consumer resists to it, its existence is enough to lower utility. Temptation is a rational to engage in pre-commitment. If this is not available, agents may consume the sin good compulsively.

[10] The problem might arise in other contexts of changing tastes (changes in visceral influences or in reference points).

error in predicting the increase in the desire for the good (Loewenstein et al. 2003; Chen et al., 2019). All these approaches imply an overvaluation of present consumption, that we apply to our sin good *x* by adding the parameter *e* to the standard parameter *a*. With *b*=1 and *e*>0, equation (1) becomes:

$$\max u^*(x_t, y_t, z_t) \equiv a(1+e)\ln(x_t) + gln(y_t) + z_t - cln(x_t) = [a(1+e) - \text{c}]ln(x_t) + gln(y_t) + z_t \quad (1')$$

Quantities demanded become:

$$x^* = \frac{a(1+e)-c}{p_x}$$
$$y^* = \frac{g}{p_x}$$
$$z^* = H - [a(1+e) - c + g].$$

The deviation from the standard model is thus an overvaluation of present consumption of the sin good. Let us assume that the government maximises the individual's utility as devoid from the effects of self-control problems (eq. 2), thus considering the parameter *e* as an error, that it can correct through taxation. Let us consider, for the sake of brevity, a Ramsey optimal taxation framework only. Taxes distort prices and quantities demanded become:

$$x^* = \frac{a(1+e)-c}{(1+t_x)}$$
$$y^* = \frac{g}{(1+t_y)}$$
$$z^* = H - (a - bc + g).$$

Substituting quantities demanded into equation (1') the government's maximand function becomes:

$$W = [(a(1+e) - c)ln\frac{(a(1+e)-c)}{(1+t_x)} + gln\left(\frac{g}{1+t_y}\right) + H - (a(1+e) - c + g) = (a(1+e) - c)\,ln\frac{1}{(1+t_x)} + gln\frac{1}{(1+t_y)} + (a(1+e) - c)\ln(a(1+e) - c) + glng + H - (a(1+e) - c + g)] \quad (2c)$$

Since $(a(1+e) - c)\ln(a(1+e) - c) + glng + H - (a(1+e) - c + g)$ is independent of taxes, the government chooses tax rates to max the following equation :

$$[a(1+e)-c]ln\frac{1}{(1+t_x)}+gln\frac{1}{(1+t_y)}$$

(2c')

s.t. $t_x\frac{(a(1+e)-c)}{(1+t_x)}+t_y\left(\frac{g}{1+t_y}\right)=R.$

Following the same procedure used above, we derive the optimal tax rates:

$$t_x^*=\frac{R}{a(1-e)-c+g-R}+\frac{(\frac{aeg}{(a-c)})}{a(1-e)-c+g-R},$$
$$t_y^*=\frac{R}{a(1-e)-c+g-R}-\frac{ae}{a(1-e)-c+g-R}.$$

Again, x is taxed, while y is subsidised; and also in this case, in a context with heterogeneous individuals, differing both in the standard parameters (a, c, g) and in the error parameter e, deviations from $e = 0$ cannot be detected on the basis of the amount consumed, unless in the $a = c$ case, with non-emotional individuals not consuming the sin good at all.

5. Efficiency and distributive effects of taxation

The literature on sin goods taxation reviewed above finds that sin taxes can, under some conditions, result in a Pareto improvement (see, for instance, O'Donoghue and Rabin, 2006, in the case of a sin tax returned to consumers by means of a lump-sum subsidy).[11] These conditions are basically two: rational individuals consume a smaller amount of the sin good than irrational ones; and irrational individuals' consumption is price elastic. Thus, on the one hand, taxation of the sin good redistributes income from irrational to rational

[11] Camerer et al. (2003) argue that the sum of consumer and producer surplus increases with policies that help consumers not to make errors, even if firms may benefit exploiting them.

individuals, while irrational individuals benefit because the tax counteracts over-consumption.

However, if individuals differ both in the error parameter and in tastes, the first hypothesis does not necessarily hold. Heavy consumers of the sin good could be rational individuals with a strong taste for it, and they could suffer both for the distortion and for the redistribution effect.

As for the second assumption, the extent of the correction effect benefiting irrational consumers depends on their price elasticity of demand: it will be high if price elasticity is high (unless people can turn to other unhealthy, but untaxed substitutes) [12], and low if price elasticity is low. Within the theoretical frameworks analysed above, if the mistake derives from the influence of visceral factors, it is plausible to assume that elasticity is low. In this case, a greater effect on quantities consumed might be achieved with different forms of intervention, such as advertising and marketing restrictions or the introduction of counter-cues (Hoch and Loewenstein, 1991).

A connected issue, central in the political debate on sin taxes, stems from their potentially regressive impact: if poor individuals consume sin goods more (see, among others, Gruber and Koszegi, 2004; Goldin and Homoroff, 2013; Alcott et al., 2014 and 2019b for related evidence), the positive correction effect of taxation would entail a regressivity cost.

From a theoretical point of view, Becker and Murphy (1988) find a relationship between addictive goods consumption and income through the effect on labour productivity. The same arguments can in principle be applied

[12] This suggest that sin taxes should apply to all goods with similar unhealthy characteristics and self-control problems - which is not easy, in practice, especially when it comes to foods and beverages.

to sin goods, given that their consumption has a negative impact on health and therefore on productivity. Thus, if consumption of the sin good reduces more the productivity of skilled jobs, that is, it has larger effects on higher earnings, the good becomes an inferior one. Becker and Murphy (1988) apply the result to the developments of tobacco consumption, that has witnessed an increase of the share of low-income consumers. They explain this with the spreading of information on the costs deriving from smoking, which has lowered its income elasticity, making it an inferior good.

The fact that poor consumers pay more for sin taxes out of their income than rich ones is not a sufficient element to judge upon the overall impact of the measure: the use of their revenues should also be considered. For instance, Lockwood and Taubinski (2017) consider the options of ‘recycling’ resources to increase the progressivity of the income tax or for expenditure programs that benefit the poor; they argue that they will be effective if sin goods consumption depends on income elasticity rather than on tastes. Cremer et al. (2012) and Wang et al. (2017) propose subsidies to health investment.

Moreover, the benefit for the increase in welfare deriving from the Pigouvian tax should also be considered. With respect to this, one can note that the link between income level and consumption of the sin goods also has implications for the extent of price elasticity and, therefore, the corrective impact of taxation. According to the Corlette and Hague (1953) rule, a low price elasticity of the demand for sin goods should be expected if these are complements to leisure. According to some survey studies, activities undertaken during free-time significantly vary with the income level. In particular, rich people are found to devote time to playing sports and attending performing arts events, while poor ones to watching television.[13] It seems plausible that the former amusements are less complementary to sin goods consumption than the latter are. Of course, a low elasticity implies a low change in quantity and, therefore, a relatively low corrective effect.

This is true if poor consumers disproportionately consume sin goods not just because of a stronger taste for it, but because their choices are more biased by self-control problems. Psychologists have actually found that poverty reduces self-control, by impeding cognitive functions (Mani et al., 2013) and inducing an orientation towards immediate needs (Lamm et al., 1976). Moreover, self-control is something that people learn. With reference to discount functions, Strotz (1955-56) argues that, besides pre-commitment, a strategy to avoid always repudiating plans is to substitute the exponential discount function for our natural one, which is possibly hyperbolic. This usually happens because people are taught to plan consistently since their early years.[14] Analogous considerations may apply to the ability of refraining from emotional, impulsive choices, as in the case of the self-control problem stemming from visceral influences. Under this respect, one should notice that financial poverty usually accompanies time poverty (Harvey and Mukhopadhyay, 2007), leaving less time for parents to teach children.[15]

Then, if poor consumers are those that exhibit an overconsumption of sin goods because of more pronounced self-control problems, investing revenues

[13] See, for instance, the American Time Use Survey, available at bls.gov/tus/. This is not only due to differences in prices: poor people also walk or run less than richer ones, possibly because they often live in unsafe areas.

[14] "Children are known to discount the future most precipitously and the "virtue" of frugality is something to be instilled when building "character". True discount functions become sublimated by parental teaching and social pressure, and the inconsistency problem … becomes lost from sight. (p. 177)".

[15] These arguments apply not only to rationality, but also to sophistication. For a tailoring of policies to the degree of sophistication, see Frederick et al. (2002).

in educational services, such as pre-school programs, might increase the overall corrective effect of sin goods taxation and help overcoming regressivity costs.

6. Conclusions

The social value recognised to health has been increasing through time, so that unhealthy goods have entered the list of demerit goods, involving a justification for taxation, since their consumption, though in line with individual tastes, contrasts with community values. The economic literature has, however, developed a new category of goods, the sin goods, distinguished from traditional merit goods. Moreover, it has developed optimal taxation models that deliver, under some conditions, the result of a Pareto improvement by combining sin goods taxation and redistributive transfers.

Sin goods combine the damage to health with a self-control problem: their overconsumption is thus regretted afterwards by individuals themselves. Regret stems from a divergence between short-run and long-run utility, generating behavioural errors because of impatience. Existing contributions can be divided into two categories, according to the source of impatience: individuals discount the feature hyperbolically or act under the influence of emotional, rather than rational, factors. All these factors imply a change in individual tastes, which does not constitute a mistake by itself, unless connected to a self-control problem.

In these situations, government intervention is considered justified not on merit goods arguments, but as a way to implement consumer sovereignty, impaired by individuals' errors. This argument implies that individuals perceive the wedge between self-interest and behaviour. This is definitely true for sophisticated individuals who are unable to resist overconsumption. In this case, government intervention, for instance, taxation of the sin good, is a substitute for the inability of consumers to adopt commitment strategies. But what about individuals who do not regret – still or ever – their consumption choices? In this case, it seems that the justifications for taxation or other forms of intervention fall back on merit goods arguments.

As for the welfare impact of sin taxes, the Pareto-improvement result obtained in the theoretical literature seems at odds with the real world debate on the regressivity of this kind of taxation, that implies a trade-off between efficiency improvements and regressivity costs. To analyse this trade-off, one should first consider the potential increase in efficiency and then consider if it can be shared among all the members of society. Of course, the existence of the former rests on the assumption that consumption choices are biased by a mistake, the correction of which brings about the efficiency improvement.

The corrective effect of taxation works through the increase in the price of the sin good and its effect on quantity demanded; it therefore depends on the degree of the price elasticity of demand, the lower the elasticity, the lower the Pigouvian improvement. There are some reasons why the price elasticity of the demand for sin goods might be low: overconsumption could stem from visceral factors, or sin goods could be complementary to leisure.

Moreover, in a context with heterogeneous individuals, some making biased choices, some behaving rationally, the correction that benefits the former should be compared with the distortion in the choices of the latter. The literature on optimal taxation of sin goods obtains the result that sin taxes might result in a Pareto improvement if they are combined to redistributive transfers. If the revenues of (linear) sin taxes are accompanied by lump-sum subsidies, eventually irrational individuals benefit from the correction, even if the amount of taxes paid exceeds the subsidy received, and rational ones benefit from subsidy, that exceeds the income and substitution effects of the tax.

The result obtains if two assumptions hold: the demand for the sin good is price elastic; and rational individuals consume less than irrational ones. The second assumption depends on the interplay between tastes and mistakes, as argued above.

The regressivity issue is linked to the theoretical result if those who disproportionately consume sin goods, be this because of tastes or error, are the poor ones. Theoretical models actually find that unhealthy goods are likely to be inferior, while empirical research shows that poor people consume sin goods relatively more than rich ones and that poverty favours present-oriented choices, thus increasing the likelihood of inconsistent behaviour. Moreover, sin goods are complements of leisure activities in which poor people widely spend their time, which implies a low price-elasticity of their demand for the sin goods. Thus, the increase in utility because of the correction effect of taxation risks to be outweighed by the regressivity cost. An important factor in balancing the two effects is the destination of revenues from taxation. Besides traditional measures, such as increases in the progressivity of the income tax or subsidies targeted to the poor, investment in education programs can provide a way, not only to offset the regressive impact of the tax, but also to strengthen its error-correction effect. This is because, as argued above, educational poverty might be a cause of self-control problems.

Appendix: Optimal tax rates on the sin and the healthy goods with heterogeneous individuals.

To concentrate on the role of intertemporal inconsistency, we assume that individuals differ in the value of the parameter *b* only, which is a random variable with density *f(b)* and support $b \in [0,1]$. We assume that the policy maker maximises a utilitarian welfare function, attaching an equal weight to each individual. The maximand will then be the expectation of individual welfare:

$$W^* = (a-c)lnx^* + (g+h)lny^* + z^* = \int_0^1 [(a-c)\,ln\frac{a-bc}{1+t_x} + (g+h)ln\frac{(g+bh)}{1+t_y} + H - (a - bc + g + bh)]f(b)db.$$

Taking some constants and deterministic variables out of the integral, we can write it as:

$$W^* = (a-c)ln\frac{1}{1+t_x} + (g+h)ln\frac{1}{1+t_y} + (H-a-g) + \int_0^1 [(a-c)\ln(a-bc) + (g+h)\ln(g+bh) + bc - bh]\,f(b)db$$

Substituting in the budget constraint $R = t_x x + t_y y$, the individual FOCs $x^* = \frac{a-bc}{1+t_x}$ and $y^* = \frac{g+bh}{1+t_y}$, we have:

$$\int_0^1 \left[t_x\frac{a-bc}{1+t_x} + t_y\frac{g+bh}{1+t_y}\right] f(b)db = R \qquad (1A)$$

which can be rewritten as:

$$t_x\frac{E(a-bc)}{1+t_x} + t_y\frac{E(g+bh)}{1+t_y} = R.$$

To simplify, we pose $E(a-bc) = a - cE(b) = A$ and $E(g+bh) = g + hE(b) = B$.

The budget constraint becomes:

$$t_x\frac{A}{1+t_x} + t_y\frac{B}{1+t_y} = R$$

Taking the total differential, we get:

$$\frac{dt_y}{dt_x} = -\frac{(1+t_y)^2}{(1+t_x)^2}\frac{A}{B} = -\frac{(1+t_y)^2}{(1+t_x)^2}\frac{[a-cE(b)]}{[g+hE(b)]} \qquad (2A)$$

Taking eq. (1A) and calculating the FOC w.r.t. t_x:

$$-(a-c)\frac{1}{(1+t_x)} - (g+h)\frac{1}{(1+t_y)}\frac{dt_y}{dt_x} = 0$$

Substituting from eq. (2A) for $\frac{dt_y}{dt_x}$ we have:

$$-(a-c)(1+t_x)B+(g+h)(1+t_y)A=0$$

which yields

$$\frac{(1+t_y)}{(1+t_x)}=\frac{(a-c)B}{(g+h)A}=\frac{(a-c)[g+hE(b)]}{(g+h)[g+hE(b)]}.$$

By using this expression and the government budget constraint we can derive the expressions for the optimal tax rates:

$$\begin{cases} \frac{(1+t_y)}{(1+t_x)}=\frac{(a-c)B}{(g+h)A} \rightarrow t_y=\frac{(a-c)B}{(g+h)A}(1+t_x)-1 \rightarrow t_y=\frac{(a-c)B(t_x)+(E(b)-1)(ah+cg)}{(g+h)A} & (3A) \\ t_x\frac{A}{1+t_x}+t_y\frac{B}{1+t_y}=R \rightarrow t_xA+t_y\frac{(1+t_x)}{1+t_y}B=R(1+t_x) & (4A) \end{cases}$$

Substituting from eq. (3A) for t_y and $\frac{(1+t_y)}{(1+t_x)}$ into eq. (4A) we have:

$$t_xA+\frac{(a-c)B+t_x(a-c)B-(g+h)A}{(g+h)A}\cdot\frac{(g+h)A}{(a-c)B}\cdot B=R(1+t_x)\ ,$$

and, simplifying:

$$t_x=\frac{R}{(A+B-R)}+\frac{\left[\frac{(g+h)}{a-c}\right]A\pm B}{(A+B-R)} \qquad (5A)$$

or, in extensive form:

$$t_x^*=\frac{R}{[a+g-R+E(b)(h-c)]}+\frac{\left[\frac{(1-E(b))(ah+cg)}{a-c}\right]}{[a+g-R+E(b)(h-c)]}. \qquad (5A')$$

Substituting for t_x from eq. (5A) in eq. (3A) we obtain:

$$t_y=\frac{(a-c)B}{(g+h)A}\cdot\left[\frac{R}{[a+g-R+E(b)(h-c)]}+\frac{\left[\frac{(1-E(b))(ah+cg)}{a-c}\right]}{[a+g-R+E(b)(h-c)]}\right]-\frac{(1-E(b))(ah+cg)}{(g+h)A},$$

from which we can derive the optimal tax rate:

$$t_y^*=\frac{R}{[a+g-R+E(b)(h-c)]}-\frac{(1-E(b))(ah+cg)/(g+h)}{[a+g-R+E(b)(h-c)]}. \qquad (6A')$$

From eq. (5A'), we note that for R=0, $t_x>0\ if\ E(b)<1$ that is with individuals who underestimate the damage of the sin good. Likewise, from eq. (6A') $t_y<0\ if\ E(b)<1$ with R=0.

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