WORKING PAPERS

N° 992

January 2026

"Soda tax design under imperfect competition"

Helmuth Cremer, Catarina Goulão and Jean-Marie Lozachmeur

Toulouse School of Economics

Soda tax design under imperfect competition[1]

Helmuth Cremer
Toulouse School of Economics, University of Toulouse Capitole, France

Catarina Goulão
Toulouse School of Economics, INRAE, University of Toulouse Capitole, France

Jean-Marie Lozachmeur
Toulouse School of Economics, CNRS, University of Toulouse Capitole, France

January 13, 2026

[1]We thank Parke Wilde, Philippe Bontems, Fabrice Etilé and the participants of the The Food and Health Economics Workshop in Toulouse for their helpful comments and suggestions. Financial support from ANR under grant ANR-17-EURE-0010 (Investissements d'Avenir program) and from the Chaire "*Marché des risques et creation de valeur*" of the FdR/SCOR is gratefully acknowledged.

Abstract

Health damages of an unhealthy good, such as a sugar-sweetened beverage, are misperceived by consumers. Market power affects both output and sugar content and these effects have to be balanced against Pigouvian considerations. Under "pseudo" perfect competition, a Pigouvian tax proportional to sugar content is sufficient to achieve a first best solution. Under monopoly, a specific tax on output achieves an efficient solution, but it must be an *affine* function of the sugar content. The calibrations of the French and US markets illustrate that both the total tax as well as its sugar component can be positive or negative.

Keywords: sin tax, tax incidence, misperception, monopoly
JEL Codes: H22, I12, D42

1 Introduction

In 2022, 43% of the world's population was overweight.[1] More than 60% of the US and European populations were overweight, with 28% and 23% obese, respectively (official numbers from 2016).[2] Being overweight or obese constitutes a major risk factor for non-communicable chronic diseases, such as diabetes, cancer or cardiovascular conditions, which are the leading cause of death worldwide WHO (2018).

A possible explanation for unhealthy eating and, in particular, unhealthy food intakes, is that individuals misperceive foodstuff attributes (Bollinger et al. 2011, Barahona et al. 2023, among others). For example, not knowing exactly, or being inattentive to, the sugar contents of a soda. But even if foodstuff attributes were fully perceived, consumers may be unable to fully understand the future adverse health effects of its intakes (see, for instances, Allcott et al., 2019b and Goulão and Pérez-Barahona, 2014). Alternatively, individuals may be subject to problems of self-control in their consumption (Sadoff et al. 2020; Gruber and Koszegi, 2004; O'Donoghue and Rabin, 2006; Kotakorpi, 2008; Haavio and Kotakorpi, 2011; Cremer et al., 2012 and Cremer et al., 2016). In the three cases, individuals make their consumption decisions according to a "perceived" or short-run utility function, which does not fully account for the long-run harmful impact of these goods on their health. Consequently, the *laissez-faire* solution will be "inefficient" in the sense that consumers' long-run utility would be larger if these internalities were properly accounted for in their consumption decisions. This may call for policy intervention aimed at reducing the consumption of unhealthy goods and/or their fat or sugar content.

Increasing the price of unhealthy foods and beverages through taxes is a potential policy measure by which to discourage over-consumption. Sodas are a natural target because they lack any nutritional content while being, generally, calorically dense.

During the last decade, we have observed the adoption of taxes on sugar-sweetened beverages (SSB) in as many as 108 countries worldwide, with many others considering it (WHO, 2023). The literature suggests that soda taxes can effectively reduce purchases, but their long-run health effects remain debated; see Bonnet and Réquillart (2013), Cornelsen and Carreido (2015), Allcott et al., (2019b), Dubois et al., (2020). Yet, it is striking to note how much these taxes on SSB vary in form and level. Many countries, such as France, Mexico and some US cities, first adopted

[1] https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight, accessed on March 28, 2024.

[2] Overweight and obesity prevalence rates available from the World Health Organization (WHO), Global Health Observatory data repository, http://apps.who.int/gho/data/node.main.NCDMBMIOVERWEIGHTC?lang=en, accessed on March 28, 2024.

specific taxes per liter or ounce. As of 2022, this was still the case of 3/4 of the countries. The United Arab Emirates, on the other hand, apply an *ad valorem* tax of 50% on SSB, and there is recently the tendency for a several-level specific tax based on sugar content, as seen in the UK and France (all figures from WHO, 2023).

The effectiveness of a tax in reducing the consumption of unhealthy foods and beverages depends on its design. Should the tax be imposed on sodas *per se* or, alternatively, on their sugar content? In either case, what would be the appropriate level of this tax? And how would producers reformulate their products in response to the tax? How would reformulation depend on market structure? Indeed, most markets for SSBs are imperfectly competitive. Taxes will and should affect not only consumption but also the nature of the good, and specifically its sugar or fat content; see, for instance, Hamilton and Requillart (2017), and Barahona et al. (2023). In this context, the appropriate design of taxes is more complex.

We develop a stylized setting that allows us to address these questions. For simplicity of exposition, we concentrate on SSBs and their sugar content, but our analysis also applies to fatty goods, for instance. The setting is a standard Mussa and Rosen (1978) type of vertical product differentiation with some customizing to fit our problem. In particular, we consider consumers differing in their instantaneous utility for SSB, which can be thought as a taste-based preference without health considerations. Sodas intake cause a health cost which may be misperceived meaning that a consumer's willingness to pay does not necessarily increase in the sugar content. We solve this model analytically and determine optimal policies for the implementation of the first-best. As a reference, we first study the solution under "pseudo" perfect competition (generalized to account for the endogenous choice of sugar content). We show that in that case, a simple Pigouvian tax of a constant amount per unit of output but proportional to the sugar content is sufficient to achieve a first best solution. Then we consider a monopoly for which the tax design is more complex. Market power affects both output and sugar content, possibly in opposite directions, and these effects have to be balanced against Pigouvian considerations. We show that, nevertheless, a tax per unit of output achieves an efficient solution, but it must be an *affine* function of the sugar content; taxing "grams of sugar" is no longer sufficient. What is more, under a monopoly a subsidy on sugar is needed if misperception is low enough.

We calibrate the model for the US and French SSB empirically relevant demand conditions and simulate the monopoly scenarios. The examples illustrate how the degree of misperception plays a crucial role in either taxing or subsidizing sugar. Furthermore, since the monopoly setting is admittedly extreme, we also simulate duopoly scenarios. These show how the results are affected when market power is mitigated. In the process we can examine how policies targeted to high and low sugar content variants should be designed. Interestingly, both the total tax and its sugar component can be positive or negative depending on the interactions between preferences, and in particular the Pigouvian component, and market power.

We finish by showing that the results hold in a more generalised model where we trade-off less restrictive preferences for a representative consumer. To enhance comparison with previous sections, we consider as well the solution under "pseudo" perfect competition and monopoly.

Our paper relates to a branch of the literature on mutidimensional market failures. Innes (1996) and Fullerton and West (2002, 2010) have made the point that a linear price policy was not enough to restore optimality when there are several sources of externality. They use the automobile market as an illustration of their argument and show that a per-galon fuel tax alone can not internalize both optimal consumers' millage decision and the purchase of automobiles with optimal emission abatement properties. Fullerton and West (2002, 2010) extend the analysis by adding heterogeneity of consumers preferences. More recently, Allcott et al. (2014) combine both externalities and heterogeneous internalities across consumers, which boils down to consumers' choices differing in their degree of non-optimality. As a result, these can only be corrected on average.

Other authors have focused on how the market portfolio of products changes because of strategic firms reacting to price policies, as in Barahona et al. (2023), Hamilton and Réquillart (2017), and O'Connell and Smith (2024). We contribute to this literature by highlighting the mechanisms leading to the need to tax liters of soda and grams of sugar in the context of market power and internalities.

The remainder of this article is organized as follows. Section 2 solves a simplified model which is calibrated for the French market in Section 3. Section 4 generalises the main lessons and Section 5 concludes.

2 The setup

We use a product differentiation model inspired by Mussa and Rosen (1978) which has by now become a classical setup used in the IO literature. An unhealthy good, soda, can be produced with sugar content s with a linear technology; per unit production costs are constant in quantity and given by $c(s) = cs$, with $c > 0, s > 0$.

Individuals consume the numeraire good y and may buy either a unit of soda, of sugar content s, or none at all. Their exogenuous income is equal to m. Consumers have heterogeneous preferences. They differ in their taste for sugar content θ, which is uniformly distributed over the interval $[0, b]$, with $c < b$. In the long run, consumption of the unhealthy good causes overweight or obesity, along with associated health problems. These negative effects of the unhealthy good consumption are captured by the harm function $h(s)$. For the sake of the present illustration, we assume $h(s) = \gamma\,(1/2)\,s^2$, with $\gamma > 0$. These assumptions are consistent with the medical literature that establishes that both weight gain and blood sugar levels depend directly on sugar intake (see Grummon et al., 2019, and the references therein).

Individuals' true utility is given by

$$U = \theta s + y - h(s), \tag{1}$$

when consuming one unit of soda and $U = m$ otherwise.

The health effects of unhealthy diet tend to occur later in life and the full understanding of their occurrence is difficult. Thus individuals may not perceive fully these effects (see Devaux et al., 2011, and Allcott et al., 2019b, among others). Their perceived harm function is given by $\beta h(s)$, where $\beta \in]0, 1]$ so that their perceived utility when consuming one unit of soda is given by:

$$\hat{U} = \theta s + y - \beta h(s). \tag{2}$$

The parameter β can be seen as synthetizing all possible behavioral mistakes that may occur because of misperception of health effects or due to present focus preferences.[3]

Misperception of health effects is a source of internality that prevents individuals from making optimal choices. In reality, misperception of health effects varies across individuals and is likely to be negatively correlated with individuals' education and income (see Allcott et al., 2019b). To make our point evident we simplify by assuming the same misperception across individuals and abstract from redistributive concerns. Nevertheless, we allow for heterogenuous preferences for soda as captured by the distribution of θ.

[3]The empirical litterature provides evidence of misperception of both food attributes and health effects of food intakes (see for instances Allcott et al., 2019b and Bernheim and Taubinsky, 2018 and the references therein.)

2.1 First Best, many variants

Consider a First Best unconstrained by the number of varieties of sodas available. For each type of consumer with taste parameter θ, Pareto-efficiency requires surplus maximization of consumers' true surplus

$$\max_s U = \theta s + m - cs - h(s). \tag{3}$$

We can substitute $h(s)$ by its specific form, solve the FOC for s, and define the surplus maximizing level of sugar of each consumer type θ as

$$s^*(\theta; 1) = \frac{\theta - c}{\gamma}. \tag{4}$$

Optimality requires each consumer with sufficiently high taste parameter θ to be consuming one unit of soda with sugar content $s^*(\theta, 1) > 0$, where 1 stands for full perception of health effects ($\beta = 1$). Consumers with low preferences for sugar ($\theta < c$) are out of the market and all consumers with taste parameter $\theta \in [c, b]$ consume a unit of soda.

2.2 Pseudo-Perfect Competition

Consider now the case of the "pseudo perfect competition" presented by Mussa and Rossen (1978). Suppose that for any variant of soda, defined by its sugar content s, producers and consumers are price takers. Therefore each soda with sugar content s is supplied at marginal cost of production, $p = c(s) = cs$, and consumers face a price for each variety of soda of sugar content $q(s) = p(s) = c(s)$.

Consumers make their consumption decisions according to their perceived utility function, and not their true utility. They decide whether to abstain from consumption or consume their most preferred unit of soda.

Individuals maximize

$$\hat{U} = \theta s + m - q(s) - \beta h(s). \tag{5}$$

Let $\hat{s}$ represent consumers' perceived most preferred level of sugar content given by the maximization of (5) where whe have replaced $q(s) = cs$ and $h(s)$ to obtain

$$\hat{s}(\theta; \beta) = \frac{\theta - c}{\beta\gamma}. \tag{6}$$

As expected, consumers prefer higher levels of sugar than optimal, i.e., $s^*(\theta;1) < \hat{s}(\theta;\beta)$ for all taste parameter θ. Yet the size of the market is equal to that of the first best, since consumers with taste parameter $\theta > c$ consume sodas with positive levels of sugar.

Note as well that

$$\frac{\partial \hat{s}}{\partial \beta} = \frac{\theta - c}{\gamma}\left(-\frac{1}{\beta^2}\right) < 0 \tag{7}$$

$$\frac{\partial^2 \hat{s}}{\partial \theta \partial \beta} = \frac{1}{\gamma}\left(-\frac{1}{\beta^2}\right) < 0, \tag{8}$$

meaning that higher misperception, i.e., lower β, increases the most preferred level of sugar content and this effect is greater the higher the taste for sugar, i.e., the magnitude of the effect of misperception is increasing in θ.

Table 1 presents sugar content, consumer prices without taxes and market coverage for the pseudo perfect competition and first best. The decentralization of the First Best requires $s^*(\theta;1) = \hat{s}(\theta;\beta)$ which can be achieved by increasing consumer's price by a proportional tax on sugar content such that $q(s) = cs + \tau s$. The tax $\tau = (1-\beta)(\theta - c)$ decentralizes the first best by making each consumer choosing the soda with the appropriate level of sugar; presented in Table 2.

2.3 Constrained First Best, one variant

We focus now on a setting where maximization of consumer surplus is constrained to the use of one soda variant. Our aim is to contrast this solution to the one of a monopoly offering one variant of the good alone in Section 2.4. Let θ_p denote the marginal consumer indifferent between consuming one unit of soda of variant s or none at all. It is defined by the level of θ_p that satisfies:

$$\theta_p(q, s; \beta) = \frac{q + \beta h(s)}{s}. \tag{9}$$

Demand for the unhealthy good is then given by:

$$x\,(q, s; \beta) = 1 - \frac{1}{b}\max[0, \theta_p(q, s; \beta)]. \tag{10}$$

For future reference note that

$$\frac{\partial x}{\partial s} = -\frac{1}{b}\frac{\partial \theta_p}{\partial s} = -\frac{1}{b}\left(\frac{1}{2}\beta\gamma - \frac{q}{s^2}\right), \tag{11}$$

and that (11) is decreasing in β. Consequently a higher degree of misperception (a lower β) implies that demand becomes more responsive to sugar content. Additionally, demand decreases

	s	q	x
Pseudo-Perfect Competition	$\frac{\theta-c}{\beta\gamma}$	$\frac{c(\theta-c)}{\beta\gamma}$	$\frac{b-c}{b}$
First Best (many variants)	$\frac{\theta-c}{\gamma}$	–	$\frac{b-c}{b}$
Monopoly	$\frac{2(b-c)}{3\gamma\beta}$	$\frac{2(b-c)(b+2c)}{9\gamma\beta}$	$\frac{b-c}{3b}$
First Best (one variant)	$\frac{2(b-c)}{3\gamma}$	–	$\frac{2(b-c)}{3b}$

Table 1: "Pseudo-perfect competition", monopoly, and first best solutions.

in s, for $s > \sqrt{2q/\gamma\beta}$, and increases for $0 < s < \sqrt{2q/\gamma\beta}$. Also note that the threshold is decreasing in β, that is, higher misperception (lower β) increases the interval where demand increases with sugar content.

To determine the First Best solution, we set the consumer price equal to marginal cost (with respect to quantity) and substitute q by $c(s)$ in (9). Health effects are fully perceived and $\beta = 1$. The First Best level of sugar is then given by:

$$s^* = \arg\max_s W = \int_0^{\theta_p(c(s),s;1)} m d\theta + \int_{\theta_p(c(s),s;1)}^{b} (m - c(s) + \theta s - h(s)) \, d\theta. \tag{12}$$

2.4 Monopoly

Supply price price p is given by the consumer price q adjusted by taxes or subsidies. We follow by showing that the first best can be decentralized via a combination of a per unit tax and a sugar content tax, $t = \bar{t} + \tau s$. We incorporated it in the expression for the profit function, to which we now turn.

Using demand $x(q, s; \beta)$ as given by (10), the monopoly solves:

$$\{q^m, s^m\} = \arg\max \{(q - \bar{t} - \tau s - c(s)) \, x(q, s; \beta)\}. \tag{13}$$

Solving (13) and (12) for $h(s) = \gamma(1/2)s^2$ and $c(s) = cs$, using (9) and (10) and rearranging, yields the values for sugar content, consumers prices and demand in the monopoly solution without taxes and in the first best presented in Table 1.

Comparing the no tax monopoly solution to the first best solution yields $x^m < x^* < b$, and $s^* < s^m$. As expected, the first best solution implies a larger output, but the monopoly is choosing an excessive sugar content.

The first best can be decentralized through the combination of a per unit tax and a sugar content tax as specified in Table 2.

	$\bar{t}$	τ	$t = \bar{t} + \tau s^*$
Pseudo-Perfect Comp.		$(1-\beta)(\theta - c)$	$\frac{(1-\beta)(\theta-c)^2}{\gamma}$
Monopoly	$-\frac{2(b-c)^2(2-\beta)}{9\gamma}$	$\frac{(b-c)(1-2\beta)}{3}$	$-\frac{2(b-c)^2(1+\beta)}{9\gamma}$

Table 2: Taxes implementing the first best.

As the monopoly is under-providing quantity, the consumer price has to decrease (negative per unit tax) so that demand increases for all levels of β. More interestingly, we obtain that even though the monopoly chooses a sugar content that is too high ($s^* < s^m$), it may be optimal to subsidize the sugar content. More precisely, we have $\tau < 0$ if and only if $\beta > 1/2$, that is when misperception is sufficiently small. To understand this result, consider a hypothetical scenario where s can be controlled directly and set to s^*. To implement the FB level of x one then can rely on a tax on output only, and simply set $\bar{t}$ to the level of t specified in the table. The relevant question is then if starting from this solution, the monopoly finds it profitable to increase or to decrease s. This in turn depends on the sign of

$$\frac{\partial \pi(x^*, s^*)}{\partial s} = (q^* - cs^* - t)\frac{\partial x}{\partial s} - cx^*$$

which using expression (11) can be rewritten as

$$(q^* - cs^* - t)\left(-\frac{1}{2}\beta\gamma + \frac{q^*}{s^{*2}}\right) - cx^*, \tag{14}$$

where $(q^* - cs^* - t) > 0$ because by FB implementation requires that the monopoly's profits are positive. When this expression is negative, the monopoly can increase profits by lowering s. To make this unattractive to the firm and to implement s^* (without controlling it directly) we then have to subsidize s. When, by contrast, the expression is positive, the monopoly wants to set s above s^* and a tax on sugar is necessary. This explains why the optimal tax mix may imply a subsidy or a tax on s.

To understand the role played by β in determining the relevant case, note that the first term in (14) represents the demand effect while the second term is the cost effect. When β is large misperception is small and consumers are sufficiently aware of the health effects so that an increase in s has a small (or possibly even negative) effect on demand. Consequently, the cost effect dominates. On the other hand, when β is sufficiently small, the demand effect is large and outweighs the cost effect. The numerical examples in the next section confirm this intuition.

In this oversimplified setting we want to highlight that taxing sugar is no longer sufficient when there are two sources of market failure, namely market power on the supply side and misperception of health effects on the demand side of the market. In fact, the presence of these two sources of market failure, requires two policy instruments for optimality and taxing sugar needs to be supplemented with taxing liters of soda as well.[4] We proceed by illustrating this result both when one or several variants of the product are available, and contrast First Best solutions to imperfect and perfect competition settings.

3 Numerical illustrations

The stylized model above allows us to provide numerical solutions for the optimal policy for calibrated versions of the model, which offer a stylized representation of the demand side of the French and US soda markets. In addition to the monopoly scenario, we also consider the implications of a duopoly. In reality neither a monopoly nor a duopoly mimic the SSB market structure. However, simulations of these two cases for empirically relevant demand conditions show how the results are affected when market power is mitigated. Additionally, by considering a duopoly we can examine how policies targeted to high and low sugar content variants should be designed. The main lessons are not specific to the French context. In Appendix C, we demonstrate that these insights remain valid when calibrated to the US market.

We first consider the extreme case of a monopoly supplying a single variant of SSB characterized by its sugar content. This provides a numerical illustration of the analytical example presented in Section 2. We then depart from the monopoly by considering a duopoly, with firms competing in sugar content and price. Following the product differentiation literature we consider a sequential game. In the first stage, firms simultaneously choose the sugar content of their variant and, in the second stage, they simultaneously set prices. We determine the subgame perfect equilibrium of this game. As a duopoly with two products is not immediately comparable with a monopoly, we also consider a monopoly supplying two variants of SSBs. Note that this solution can also be interpreted as a duopoly in which the firms collude and maximize joint profits. Adding this extra scenario allows us to disentangle market power and product variety effects. We provide numerical solutions for the optimal taxes for these various scenarios which represent different degrees of market power.

[4]Note that if we had assumed heterogeneous bias across consumers the correction of the demand side market failure would require individualised taxes as in the case of pseudo-perfect competition, see Table 2. In our pseudo-perfect competition setting individualised taxes come from the need of correcting individualised mistakes which are a combination of homogenous bias and heterogenuos tastes. With heterogenous bias across consumers optimal taxation would require as well individualized taxes that would correct individual mistakes resulting from both heterogenuous bias and tastes.

Parameter	France	US
ε_{xq}	-3.5	-1.44
b	0.0343	0.0430
γ	0.0006	0.0006
c	0.0231	0.0231
β	0.87	0.87

Table 3: Parameters used in calibration

Table 3 sums-up parameters used. Details on the calibration of the parameters and sources used are provided in Appendix B. As explained there, the empirical literature has shown that demand for SSB in the US is higher and less elastic than in France. Specifically the US and French demand elasticities are set at $\varepsilon_{xq} = -1.44$ (Allcott et al. 2019, b) and $\varepsilon_{xq} = -3.52$ (Bonnet and Réquillart, 2013) respectively, while the upper bounds of the distribution of θ's (which determine the levels of demand) are given by $b = 0.0430$ and $b = 0.0343$ repectively. Following Allcott et al. (2019b)'s estimations we set $\beta = 0.87$ in the baseline case and consider the benchmark values of $\beta = 0.4$ and $\beta = 1$ (no misperception) as well.

Table 4 reports the results for the baseline scenario for France with $\beta = 0.87$ (see Table 8, in Appendix C for the equivalent US results). The first two columns provide the first best and the monopoly solution. The bottom part of the table specifies the taxes that would implement the first best. As anticipated from the analytical example, monopoly output would be too small ($x_F^m = 0.11$, $x_F^* = 0.21$) but with an excessive sugar content ($s_F^m = 14.30$, $s_F^* = 12.44$, where we use the subscript F to denote France, and US the US, mostly in Appendix C). Achieving a FB output level requires a total subsidy of -0.0869 €/ℓ. Since misperception is rather low ($\beta = 0.87$), we are in the case where the cost effect in expression (14) dominates so that a subsidy on sugar ($\tau = -0.0028$) is necessary to avoid that the monopoly reduces the sugar content below its optimal level.[5]

The remaining columns in Table 4 consider scenarios with two variants. They present the FB and the subgame perfect equilibrium of the duopoly when firms set sugar levels and then prices. The last column represents the multiproduct monopoly (duopoly with collusion). The marginal consumer θ_{p1} is indifferent between the low sugar content variant and not consuming the product. Consumer θ_{p2} is indifferent between the two variants. Demand for the low sugar variant is thus

[5] In Appendix B, Table 7 shows the values of the partial derivative of the monopoly profit with respect to the sugar content at the First Best allocation (x^*, s^*). For the baseline calibration $\beta = 0.87$, the value of the derivative is negative, meaning that the monopoly increases profits by decreasing sugar content. To avoid a value of sugar below s^*, a subsidy on sugar is necessary.

	First best	Monopoly	First Best	Duopoly	Collusion
s_1	12.44	14.30	7.47	8.55	8.58
s_2			14.93	17.58	17.16
θ_{p1}	0.0268	0.0306	0.0253	0.027	0.030
θ_{p2}			0.0298	0.031	0.032
% mkt_1	0.22	0.11	0.31	0.11	0.065
% mkt_2			0.31	0.09	0.065
q_1		0.38		0.21	0.24
q_2				0.43	0.45
Taxes implementing the first-best solutions					
$\bar{t}_1$		-0.0525		-14.98	-0.02
τ_1		-0.0028		2.01	-0.006
$t_1 = \bar{t}_1 + \tau_1 s_1^*$		-0.0869		-0.01	-0.06
q_1		0.29		0.17	0.17
$\bar{t}_2$				0.31	-0.08
τ_2				-0.02	-0.001
$t_2 = \bar{t}_2 + \tau_2 s_2^*$				-0.02	-0.09
q_2				0.35	0.35

Table 4: Taxes calibration implementing the first best for France with: $\beta = 0.87$, $\gamma = 0.0006$, $\varepsilon_{xq} = -3.52$, $c = 0.0231$, $b = 0.0343$. Sugar content is in g/ℓ, prices and taxes are in €$/\ell$.

given by $(\theta_{p2} - \theta_{p1})/b$, while that for the high sugar variant is given by $(b - \theta_{p2})/b$. This solution yields higher sugar contents and lower output levels than in the FB for both variants. We have $s_{1F}^m = 8.58$ and $s_{2F}^m = 17.16$ each of which is higher than their FB counterparts $s_{1F}^* = 7.47$ and $s_{2F}^* = 14.93$. Each variant is covering 0.065 of the market as opposed to 0.31 in the FB.

When the two variants are produced by competing firms, the degree of product differentiation increases albeit slightly: sugar content decreases for the low-sugar content SSB, and increases for the high-sugar content SSB ($s_{1F}^d = 8.55$ and $s_{2F}^d = 17.58$). This is in line with standard results obtained in the IO literature; competing firms tend to increase the degree of product differentiation in order to mitigate price competition intensity. Still, as market power decreases, so do prices and demand levels increase, resulting in total market coverage of 0.20.

In our view, the interesting results is the appropriate policy design. This is not discussed in Section 4 because even for the simple setup of Section 2 the expressions are complex and not very telling, particularly for the duopoly case. The The numerical results are presented in the lower part of the last two columns. In both scenarios, the FB with two products can be implemented with *product specific* per unit taxes which are an affine function of sugar contents $t_i = \bar{t}_i + \tau_i s_i$. As with a single product, sugar contents and final products are subsidized for the two products of the monopoly (the collusion scenario). However, in a duopoly the low sugar content SSB faces a tax on sugar $\tau_{1F}^d = 2.01$ while there is a subsidy $\tau_{2F}^d = -0.02$ for the high sugar content variant. Intuitively these results arise for the same reasons as under a single product monopoly. When the FB output is with a subsidy on output levels firms may have an incentive to choose a sugar content different from the FB level. As explained in the discussion of expression (14) deviating from the FB levels has demand and cost effects. While the cost effect is similar here, demand effects are more complex, especially in the duopoly, where the change in s induces changes in the second stage equilibrium prices. However, the basic intuition continues to hold: when starting from an implementation with an output tax only, the firm finds it profitable to increase sugar content (that is when the demand effect outweighs the cost effect), then there should be a tax on sugar. In the opposite case, a subsidy on sugar content is again optimal. The numerical results show that the latter case applies for both variants in the monopoly case but only for the high sugar variant in a duopoly where the low sugar content variant now faces a tax on sugar.

The calibrations of the French SSB market and the estimations of the taxes implementing the first best illustrate the findings of our analytical model and show that the main message remains valid for a wider range of market structures. Misperception of health care cost associated with SSB consumption coupled with inefficient market structures call for more complex tax instruments. More precisely, on their own, neither a per unit tax per liter of SSB nor a tax per grams of sugar content are enough to implement the first best. Yet, using both instruments in the form of an affine per unit tax $t = \bar{t} + \tau s$ renders it possible. Note that a simple taxation of sugar would exacerbate the problem of high prices due to market power, leading to small market coverage. Furthermore, even when the market equilibrium implies an excessive sugar content, its reduction through a tax policy may call for a subsidy in sugar content $\tau < 0$ combined with a reduction in total price $t < 0$. We have illustrated this effect through the estimations provided in Table 4. Table 1 has already shown this result analytically for a monopoly where τ is negative when $\beta > 0.5$, a condition which holds for the baseline calibration. Numerical illustrations reinforce the message by showing that the policy is even more complex in a duopoly than when two variants are supplied by a single firm.

We now depart from the baseline calibration by considering alternative levels of misperception. Since our analytical results suggest that this parameter has a crucial impact on the design of the tax rule, it is important to consider scenarios with alternative assumptions.

We first consider a case with a larger degree of misperception namely $\beta = 0.4$. We already know from Table 1 that in this case the monopoly case calls for a tax on sugar content. Table

5 presents the different solutions for this level of misperception (see Table 9 in Appendix C for the equivalent US calibration). Consistently sugar content for the monopoly would be taxed in France at 0.0007 but the output price would be subsidized, which also in consistent with Table 1. In the duopoly case, a richer pattern of results emerges. Many more effects are now at work because of the strategic interaction and the two-stage nature of the game. Consequently, the country-specific parameters have crucial impact on the balance of the various effects. A tax on sugar content is now applied only to the low-level sugar content SSB. Furthermore, the final price of the high-sugar content good is taxed $t_{2_F} = 0.0067$. This reflects the fact that market power is reduced under duopoly so that there is no longer a need for a subsidy on all products to correct for this market power.

Finally, Table 6 presents the results considering no misperception with $\beta = 1$ (see Appendix C, Table 10, for the equivalent US calibration). Two facts should be highlighted. First, monopoly and collusion supply the first best levels of sugar content but underprovide quantity. Correction in quantities supplied calls for a decrease in the market price. However, in the absence of mispersception, demand decreases with sugar content so that both effects in equation (14) go in the same direction and suppliers would tend to decrease SSB's sugar content below their optimal levels. Therefore a subsidy in sugar content needs to follow a decrease in price, and τ_1 and τ_2 are negative for a monopoly with a single and with two variants. Second, in a duopoly, sugar content is taxed for each good, and τ_1 and τ_2 are both positive. This shows once again that the market structure has a drastic impact on the results. Results under single and multi product monopoly differ already significantly from those under perfect competition. And a duopoly involving strategic interactions represents an even more drastic departure with many more effects at work. Consequently, the country-specific parameters have a crucial impact on balancing the various effects. However, in Appendix C, we show that, despite the differences between the US and French figures, the qualitative results remain unchanged.

4 Generalising the model

Section 2 uses a setting where individual demand is discrete (0 or 1), but where consumers are heterogenous. Making other additional assumptions, it is suited to calibrate demand behavior, particularly in the case where two variants of the product are supplied which becomes relevant when we study the duopoly scenarios (Section 3). We now show that the main results hold in a more generalised setting of a representative consumer.

	First best	Monopoly	First Best	Duopoly	Collusion
s_1	12.44	31.11	7.47	18.61	18.67
s_2			14.93	38.24	37.33
θ_{p1}	0.0268	0.0306	0.0253	0.027	0.030
θ_{p2}			0.0298	0.031	0.032
% mkt_1	0.22	0.11	0.31	0.11	0.065
% mkt_2			0.31	0.09	0.065
q_1		0.83		0.47	0.51
q_2				0.94	0.99
Taxes implementing the first-best solutions					
$\bar{t}_1$		-0.0743		-2.3	-0.03
τ_1		0.0007		0.3071	-0.0040
$t_1 = \bar{t}_1 + \tau_1 s_1^*$		-0.0650		-0.0067	-0.0569
q_1		0.32		0.18	0.18
$\bar{t}_2$				0.125	-0.11
τ_2				-0.0079	0.0031
$t_2 = \bar{t}_2 + \tau_2 s_2^*$				0.0067	-0.060
q_2				0.39	0.39

Table 5: Taxes calibration implementing the first best for France with $\beta = 0.4$, $\gamma = 0.0006$, $c = 0.0231$, $b = 0.0343$. Sugar content is in g/ℓ, prices and taxes are in €$/\ell$.

	First best	Monopoly	First Best	Duopoly	Collusion
s_1	12.44	12.44	7.47	7.44	7.47
s_2			14.93	15.30	14.93
θ_{p1}	0.0268	0.0306	0.0253	0.027	0.029
θ_{p2}			0.0298	0.031	0.032
% mkt_1	0.22	0.11	0.31	0.11	0.065
% mkt_2			0.31	0.09	0.065
q_1		0.33		0.19	0.21
q_2				0.373	0.40
Taxes implementing the first best solutions					
$\bar{t}_1$		-0.0464		-17.56	-0.02
τ_1		-0.0037		2.350	-0.007
$t_1 = \bar{t}_1 + \tau_1 s_1^*$		-0.0929		-0.017	-0.07
q_1		0.29		0.17	0.17
$\bar{t}_2$				-0.875	-0.07
τ_2				0.056	-0.002
$t_2 = \bar{t}_2 + \tau_2 s_2^*$				-0.033	-0.10
q_2				0.34	0.34

Table 6: Taxes calibration implementing the first best for France if there is no misperception: $\beta = 1$, $\gamma = 0.0006$, $c = 0.0231$, $b = 0.0343$. Sugar content is in g/ℓ, prices and taxes are in €$/\ell$.

We depart from discrete demand and suppose individuals consume x units of an unhealthy good (soda) of sugar content s and a numeraire good y. Their exogenous income is m, as in the previous sections. Their true utility function is given by:

$$U = u(x, s) + y - h(xs), \tag{15}$$

where $u(x, s)$ reflects the short-term utility from the consumption of the unhealthy good, which depends on both the quantity consumed and its sugar content. Assume that $\partial u/\partial x > 0$, $\partial u/\partial s > 0$. Observe that one can simply think of s as "quality" , except that, unlike in traditional models, utility is not monotonic in "quality".

The negative effects of the unhealthy good consumption are captured by the harm function $h(S) = h(xs)$ with $\partial h(S)/\partial x > 0$, $\partial h(S)/\partial s > 0$ and $\partial^2 h(S)/\partial s^2 > 0$. As in the previous sections, individuals' perceived harm function is given by $\beta h(xs)$, where $\beta \in]0, 1]$ so that their perceived utility is given by:

$$\hat{U} = u(x, s) + y - \beta h(xs). \tag{16}$$

Consumers make their consumption decisions according to their perceived utility function. For given s and a consumer price q, consumers maximize:

$$\max_x \hat{U} = u(x, s) + m - qx - \beta h(xs),$$

which yields the FOC:

$$q(x, s; \beta) = \frac{\partial u(x, s)}{\partial x} - \beta \frac{\partial h(S)}{\partial S} s. \tag{17}$$

Equation (17) defines the inverse demand function $q(x, s; \beta)$ in the traditional way. For future reference, note that by adding and subtracting $\partial h(S)/\partial S s$, this can be decomposed in an inverse demand with fully perceived health effects, plus a term that accounts for misperception:

$$q(x, s; \beta) = q(x, s; 1) + (1 - \beta) \frac{\partial h(S)}{\partial S} s. \tag{18}$$

Note that since in the previous sections we have used quasi-linear preferences with discrete demand, aggregate demand (and welfare) is perfectly consistent with the representative consumer approach used here (see for instance Varian (1992), Section 9.4).

4.1 First Best

With quasi-linear preferences, Pareto-efficiency requires surplus maximization based on consumers' true utility. The efficient allocation (x^*, s^*) is thus obtained by solving:

$$\max_{x,s} W = u(x, s) + m - C(x, s) - h(xs).$$

First-order conditions are given by:

$$\frac{\partial u(x^*, s^*)}{\partial x} - \frac{\partial h(S^*)}{\partial S} s^* = \frac{\partial C(x^*, s^*)}{\partial x}, \tag{19}$$

$$\frac{\partial u(x^*, s^*)}{\partial s} - \frac{\partial h(S^*)}{\partial S} x^* = \frac{\partial C(x^*, s^*)}{\partial s}, \tag{20}$$

where $S^* = s^* x^*$ is the efficient total consumption of sugar.

4.2 Pseudo perfect competition

To obtain a perfect competition benchmark in a world where a characteristic of the product is endogenous, assume that each potential variant of the product – characterized by its sugar content s – is sold in a competitive market at price $\widetilde{p}(s)$. This equilibrium is inspired by the "competitive solution" presented by Mussa and Rossen (1978). Both producers and consumers are price-takers. Consequently, the competitive allocation (x^c, s^c) supported by the price system $\widetilde{p}(s)$ must satisfy, for all s:

$$\widetilde{p}(s^c) = \frac{\partial C(x^c, s^c)}{\partial x}, \tag{21}$$

$$x^c \frac{\partial \widetilde{p}(s^c)}{\partial s} = \frac{\partial C(x^c, s^c)}{\partial s}. \tag{22}$$

In words, both the price and the implicit price for quality must equal the respective marginal costs of x and s.

On the consumer side, the market equilibrium requires that (x^c, s^c) solves:

$$\max_{x,s} \hat{U} = u(x, s) + m - qx - \beta h(xs).$$

The FOC are given by:

$$\frac{\partial u(x^c, s^c)}{\partial x} - \widetilde{q}(s^c) - \beta \frac{\partial h(S^c)}{\partial S} s^c = 0, \tag{23}$$

$$\frac{\partial u(x^c, s^c)}{\partial s} - x^c \frac{\partial \widetilde{q}(s^c)}{\partial s} - \beta \frac{\partial h(S^c)}{\partial S} x^c = 0. \tag{24}$$

The decentralization of the first best solution requires that (21)–(22) and (23)–(24) are satisfied by (x^*, s^*) as defined by (19)–(20). This can be attained with a per unit tax on x, which is proportional, at rate τ, to the sugar content s. The consumer's expenditures for the good are then given by:

$$\widetilde{q}(s)x = [\widetilde{p}(s) + \tau s]x. \tag{25}$$

Departing from (23) and using (19), (21), and (25), decentralization then requires:

$$\widetilde{p}(s^*) + \frac{\partial h(S^*)}{\partial S} s^* - [\widetilde{p}(s^*) + \tau s^*] - \beta \frac{\partial h(S^*)}{\partial S} s^* = 0,$$

and solving for τ yields:

$$\tau^P = (1-\beta)\frac{\partial h(S^*)}{\partial S}.$$

Note that (22) and (24) are simultaneously satisfied for τ^P. Intuitively, τ^P reflects the wedge between social (true) utility and individual (perceived) utility, which determines demand. With marginal cost pricing, this Pigouvian tax on the sugar content imposed per unit of output ensures that the consumer price $\widetilde{q}(s)$ corresponds to the true marginal cost of x, which in turn implies that quantity is at its optimal level.

Therefore, under pseudo-perfect competition, a single instrument – namely a Pigouvian specific tax on the sugar content – is sufficient to achieve an optimal choice of both quantity x and sugar content s. If individuals perceive perfectly the health effects ($\beta = 1$), the tax vanishes to zero.

4.3 Monopoly

Profit maximizing solution

Consider now a monopoly producing the unhealthy good x with a given content of sugar s. It solves:

$$\max_{x,s} p(x,s;\beta)x - C(x,s),$$

where the producer price $p(x,s;\beta)$ is given by the inverse demand function defined by (18), adjusted by any applicable taxes or subsidies.

Now assume that the good is subject to a (positive or negative) per unit tax which is an affine function of the sugar content and given by $t = \bar{t} + \tau s$. We then have:

$$q(x,s;\beta)x = \left[p(x,s;\beta) + \bar{t} + \tau s\right] x. \tag{26}$$

Using it in the monopoly maximization problem, the FOCs, defining the monopoly solution (x^m, s^m) are given by:

$$q(x^m,s^m;\beta) - \bar{t} - \tau s + \frac{\partial q(x^m,s^m;\beta)}{\partial x}x^m = \frac{\partial C(x^m,s^m)}{\partial x}, \tag{27}$$

$$\left(\frac{\partial q(x^m,s^m;\beta)}{\partial s} - \tau\right)x^m = \frac{\partial C(x^m,s^m)}{\partial s}. \tag{28}$$

Decentralization of the first best

The decentralization of the first best solution requires that equations (27)–(28) and the consumer FOCs, are satisfied by (x^*, s^*). Departing from (19) and (20), and using (27) and (28), we get:

$$\frac{\partial u(x^*,s^*)}{\partial x} - \frac{\partial h(S^*)}{\partial S}s^* = q(x^*,s^*;\beta) - \bar{t} - \tau s + \frac{\partial q(x^*,s^*;\beta)}{\partial x}x^*,$$
$$\frac{\partial u(x^*,s^*)}{\partial s} - \frac{\partial h(S^*)}{\partial S}x^* = \left(\frac{\partial q(x^*,s^*;\beta)}{\partial s} - \tau\right)x^*.$$

Rearranging and solving for $t = \bar{t} + \tau s$ and τ leads to:

$$t = \bar{t} + \tau s = q(x^*,s^*;\beta) + \frac{\partial q(x^*,s^*)}{\partial x}x^* - \frac{\partial u(x^*,s^*)}{\partial x} + \frac{\partial h(S^*)}{\partial S}, \tag{29}$$
$$\tau = \frac{\partial q(x^*,s^*;\beta)}{\partial s} - \left[\frac{\frac{\partial u(x^*,s^*)}{\partial s}}{x^*} - \frac{\partial h(S^*)}{\partial S}\right]. \tag{30}$$

Differentiating inverse demand defined by (18) with respect to s shows that:

$$\frac{\partial q(x,s;\beta)}{\partial s} = \frac{\partial q(x,s;1)}{\partial s} + (1-\beta)\left[\frac{\partial h(S)}{\partial S} + \frac{\partial h^2(S)}{\partial S^2}sx\right].$$

Finally, substituting $q(x^*,s^*;\beta)$ and $\partial q(x^*,s^*;\beta)/\partial s$ in (29)–(30), respectively, yields:

$$t = \bar{t} + \tau s^* = \frac{\partial q(x^*,s^*;\beta)}{\partial x}x^* + (1-\beta)\frac{\partial h(S^*)}{\partial S}, \tag{31}$$
$$\tau = \left\{\frac{\partial q(x^*,s^*;1)}{\partial s} - \frac{\left[\frac{\partial u(x^*,s^*)}{\partial s} - x^*\frac{\partial h(S^*)}{\partial S}\right]}{x^*}\right\} + (1-\beta)\left[\frac{\partial h(S^*)}{\partial S} + \frac{\partial h^2(S^*)}{\partial S^2}s^*x^*\right]. \tag{32}$$

Expression (31) specifies the per unit tax $t = \bar{t} + \tau s$, which is designed to achieve the optimal level of output. To interpret this, suppose first that individuals perceive correctly the health effects of soda and sugar consumption ($\beta = 1$). In this case, it is sufficient to correct for the monopoly power to achieve the first best. It follows that $(t + \tau s) < 0$, and we have the standard subsidization of demand to induce a higher quantity supplied by the monopoly. When there is misperception ($\beta < 1$), this effect is mitigated or outweighed by the positive Pigouvian term, which is the same as under perfect competition and has the same interpretation as in Section 4.2. Consequently, the net sign of t is ambiguous. Intuitively, absent of misperception, the monopoly output is lower than efficient; this can be corrected by a subsidy. However, because of the misperception, the competitive output would be too large, which in turn calls for a tax. The sign of t is then determined by trading off the market power and the Pigouvian effect. This is in line with the classical result whereby, absent of any taxation or regulation, a monopoly may produce a more efficient output level of a polluting than a competitive market.

Turning to (32), recall that absent of misperception one can simply think of s as "quality", except that, unlike in traditional models, utility is not monotonic in "quality". The first term in curly brackets is the standard term measuring the sign of the quality (s) distortion in a monopoly. We know from Spence (1975) that the monopoly level of quality may be smaller or larger than efficient. This depends on the shape of the demand curve, and $s^m > s^*$ obtains when the marginal valuation of sugar content s compares with the average valuation of s. To sum up, the first term is positive if $s^m > s^*$ (so that it is desirable to reduce s from the monopoly level), and negative otherwise. Note, however, that in a two dimensional setting (both x and s are endogenous), local comparisons have to be interpreted with care. The comparison between s^m and s^* *may* depend on the level of output.[6] The relevant comparison for our purpose is the one given the first best level of output x^*. This point is illustrated by the example presented in Section 2. The second term is the Pigouvian term which vanishes when $\beta = 1$. Otherwise, it is positive.

Expressions (31) and (32) determine the "total" per unit tax t and tax on the sugar content τ. The constant in the affine per unit tax function is then simply determined as a residual with $\bar{t} = t - \tau s^*$, which can be positive or negative depending on whether the sugar component of the tax is larger or smaller than the required per unit tax on quantity. It is not in general equal to zero, which explains why under monopoly the affine function is necessary; unlike under perfect competition, a simple linear function is not sufficient.

5 Conclusion

The main lesson that emerges from this paper is that the design of the appropriate tax policy for real world SSB makets is a complex issue. In a textbook scenario with perfect competition, a Pigouvian tax on sugar content is sufficient to achieve both the optimal sugar content and output levels. Its rate corresponds to the mispercieved marginal health cost. This rule is fairly simple especially when, as we assume, the degree of misperception is the same for all. When the degree of misperception differs accross individuals, a linear tax equal to the average degree of misperception achieves a second-best solution; see Cremer et al. (2016). But the tax base continues to be solely the sugar content.[7]

But this result is valid in the textbook world only. We show that taxing sugar is indeed

[6]In other words, the sign first term in (32) may depend on the level of x. This is determined by the properties of the demand function.

[7]See also see Allcott et al., (2019 a).

necessary but may not be *sufficient* to restore optimality in non-competitive settings. Under imperfect competition with endogenous product characteristic, the appropriate tax rule is more complex. We have illustrated this point by considering, first, the simplest form of imperfect competition, namely a monopoly supplying one and then two variants of SSB. Two sources of inefficiency have to be considered. First, market power leads to inefficient output levels and sugar content, even in the absence of misperception. Second, output level and sugar content are suboptimal because of misperception. A per unit tax proportional to sugar content is no longer sufficient. We show that, nevertheless, a per unit tax continues to be sufficient, but it must be an affine function of the sugar content. In other words, the per unit tax specification contains a constant which, for practical purposes, means that "liters of soda" must also be taxed, and that this tax is in part independent of the sugar content.

We provide tax calibration if the SSB market in the US and France were monopolies or duopolies. Our estimations show that trading off inefficient output levels and sugar content could call for subsidizing sugar content even if in the end a per unit tax is imposed on SSB, and if the laissez-faire is characterized by too much sugar content.

Perfect competition and monopoly are extreme forms of market structures. Most real world markets are oligopolies, which are "in between" these extremes but also raise different challenges because they involve strategic interaction. Even if we provide estimations for the case of a duopoly, soda tax design under oligopoly is still an open question. This paper represents only a first step, which, however, is already sufficient to show that the simple "tax grams of sugar" only recommendation is not a robust result. To account for the interaction between market power and misperception more instruments will be needed, and their appropriate use will depend on the specific characteristics of the considered market.

We have used the market of SSB and their sugar content as an application, however other markets would also be as suitable illustrations; for instance, the market of breakfast cereals and their sugar content, or, alternatively, the market of processed foods and their salt content. Furthermore, whatever the considered application, one has to keep in mind that nutritional policies should account for the global effects on the whole diet, accounting for substitution and complementary effects across final and intermediate goods. From that perspective, concentrating on a single harmful substance represents only a first step which has to be supplemented by a more comprehensive approach. These issues are left for future research.

Appendix A: Calibration strategy and sources

Obtaining numerical solutions for the optimal taxes requires the calibration of the parameters β, γ, c, and b. Starting with β, we use Allcott et al. (2019 b) who define the money metrics for consumer bias as the compensated price change that produces the same effect on demand as the bias does. The authors estimate that the average marginal bias across all the American households is \$1.13 cents/oz or €0.35/ℓ. In our model this corresponds to the value of $(1-\beta)h(s)$. Therefore, knowing $h(s)$ allow us to calibrate β.

The function $h(s) = \gamma s^2/2$ represents the health impact of SSB consumption (per liter) on individuals' utility, and it can be estimated from Wilde et al. (2019). They use a synthetic population of 1 million adults aged 35–80 years and micro-simulate the impact of a 0.01/oz tax on SSB, implying a reduction in SSB consumption, on lifetime health outcomes and cardiovascular diseases-related health care costs. Using the reduction of SSB consumption and the associated health gains we can determine the average impact of a liter of SSB on health, that is the function $h(s)$.

Starting with the health gains, Wilde et al. (2019) predict that a 0.01/oz tax on SSB implies a saving of 3.40 million quality-adjusted-life-years (QALYs) as well as \$45 million saved in health care costs (Table 4 in Wilde et al., 2019). We use the most conservative valuation of a QALY of the UK National Institut for Health and Care Excellence (NICE), £20 000, to estimate that approximately €76 200 million would be saved in both QALYs and health care costs.

We turn to estimate the decrease in consumption due to the tax. Using Wilde et al. (2019)'s average price after tax, the total taxes collected and the total SSB market value after taxes we infer a total of 233 068 million liters consumed after tax. The authors suppose a price-elasticity of -0.66 (based on the meta-analysis of Afshin et al., 2017) and that taxes are 100% passed through consumers. Consequently, the 16.9% price increase due to the \$0.01/oz tax implies a decrease of 29 355 million liters of SSB consumption. Averaging, we are thus able to estimate the impact of a liter of SSB on health and health care costs. This is simply €76 200 million/29 355 million/ℓ= €2.6/ℓ. Therefore the average health impact of a 1 liter of SSB is $h(s) = \gamma s^2/2 = 2.6$€. We suppose it to be the same across populations (consumers and countries) which is obviously a simplification but it represents a benchmark. Finally, we can set value of the parameter measuring perception of health effects β. Using both $(1-\beta)h(s) =$€0.35/ℓ, and $h(s) = \gamma s^2/2 = 2.6$€, we get $\beta = 0.87$.

Turning to the parameter γ, we get it from $h(s) = \gamma/2s^2 = 2.6$, using the average sugar content of SSB in the French market ($s = 92.5g/\ell$, see Table 1 in Bonnet and Réquillart, 2013). Therefore $\gamma = 0.0006$.

To calibrate the parameter c in the cost function, we use Bonnet and Réquillart (2013) observed average sugar content of $92.5g/\ell$ and the international market value of sugar of 0.25€/kg. We get $c = 0.0231$ €$/\ell$. Bonnet and Réquillart (2013)'s observed average sugar content relates to SSB traded in the French market. We assume it to be the same in the US.

Finally, the parameter b represents the upper limit of consumers' taste distribution over sugar content. Using (10) we compute elasticity of demand where θ_p is given by (9)

$$\varepsilon_{xq} = -\frac{\partial \theta_p}{\partial q} \frac{q}{b - \theta_p}, \tag{33}$$

and solving for b gives

$$b = -\frac{1}{s} \frac{q}{\varepsilon_{xq}} + \frac{q + \beta h(s)}{s}. \tag{34}$$

For both markets we use the observed average sugar content of $s = 92.5g/\ell$, reported by Bonnet and Réquillart, (2013). We allow b to be country specific. For the US market we use Allcott et al. (2019 b)'s estimated elasticity of -1.44, and average SSB price of 1.02 €$/\ell$ (1.12 USD$/\ell$, Table 1 in Allcott et al., 2019 b), and get the value of $b = 0.0430$. As to France we use Bonnet and Réquillart, (2013)'s estimated elasticity of -3.52 and average price of 0.72€$/\ell$ and obtain $b = 0.0343$, slightly lower than in the US. The French SSB market is thus more reactive to price changes and has a lower intensity of taste for sugar. Table 3 in the text sums up all parameters used.

Appendix B

We show in Table 7 below how the value of the partial derivative of monopoly's profit with respect to s, at (x^*, s^*) can either be positive or negative, illustrating how the tax policy may require either a tax or a subsidy on sugar, respectively. When implementing FB while directly setting s^* the monopoly profit is given by

$$\pi = (q^* - c(s^*) - t)x$$

at that point, using (11)

	France	US
$\beta = 0.4$	0.0002	0.0004
$\beta = 0.87$	-0.0006	-0.0015
$\beta = 1$	-0.0008	-0.0020

Table 7: Value of the partial derivative of monopoly profit with respect to s, at (x^*, s^*).

$$\frac{\partial \pi}{\partial s} = (q^* - cs^* - t)\frac{\partial x}{\partial s} - cx^*$$
$$(q^* - cs^* - t)\left(-\frac{1}{2}\beta\gamma + \frac{q^*}{s^{*2}}\right) - cx^*$$

Now, simply set t to the level of $\bar{t}$ that descentralizes first best. Computing for our parameter values as calibrated in Appendix A we get the values of the derivative reported in Table 7.

Appendix C: Calibration for the US market

Table 8 shows that while the specific numbers differ from the French calibration, more qualitative results are the same as those discussed for France. The only exception is that in the duopoly, none of the firms faces a tax on sugar so that the firm supplying the lowest sugar content also faces a subsidy on sugar content. When considering a higher level of misperception ($\beta = 0.4$, Table 9) the main qualitative difference with respect to the French results is that on the duopoly case a tax on sugar content is applied only to the high-level sugar content SSB as opposed to the lowest one in France. Yet, in both countries the final price of the high-sugar content good is taxed $t_{2_F} = 0.0067$ and $t_{2_{US}} = 0.0211$. Consequently, the country-specific parameters have crucial impact on the balance of the various effects. Without misperception, the qualitative results of France apply to the US; see Table 10.

	First best	Monopoly	First Best	Duopoly	Collusion
s_1	22.11	25.42	13.27	15.20	15.25
s_2			26.53	31.24	30.50
θ_{p1}	0.0297	0.0364	0.0271	0.0306	0.035
θ_{p2}			0.0350	0.0374	0.039
% mkt_1	0.31	0.15	0.31	0.009	0.093
% mkt_2			0.31	0.012	0.093
q_1		0.76		0.40	0.47
q_2				0.81	0.89
Taxes implementing the first-best solutions					
$\bar{t}_1$		-0.165		0.4562	-0.0597
τ_1		-0.0049		-0.0379	-0.0109
$t_1 = \bar{t}_1 + \tau_1 s_1^*$		-0.274		-0.0459	-0.2043
q_1		0.53		0.31	0.31
$\bar{t}_2$				2.3452	-0.2387
τ_2				-0.0913	-0.0019
$t_2 = \bar{t}_2 + \tau_2 s_2^*$				-0.0781	-0.289
q_2				0.64	0.64

Table 8: Taxes calibration implementing the first best in the US with $\beta = 0.87$, $\gamma = 0.0006$, $\varepsilon_{xq} = -1.44$, $c = 0.0231$, $b = 0.0430$. Sugar content is in g/ℓ, prices and taxes are in €/ℓ.

	First best	Monopoly	First Best	Duopoly	Collusion
s_1	22.11	55.28	13.27	33.06	33.17
s_2			26.53	67.95	66.33
θ_{p1}	0.0297	0.0364	0.0271	0.031	0.035
θ_{p2}			0.0350	0.039	0.039
% mkt_1	0.31	0.15	0.31	0.16	0.093
% mkt_2			0.31	0.13	0.093
q_1		1.64		0.88	1.03
q_2				1.76	1.92
Taxes implementing the first-best solutions					
$\bar{t}_1$		-0.2347		0.7546	-0.0845
τ_1		0.0013		-0.0585	-0.0072
$t_1 = \bar{t}_1 + \tau_1 s_1^*$		-0.2053		-0.0211	-0.1795
q_1		0.60		0.34	0.34
$\bar{t}_2$				-2.266	-0.338
τ_2				0.0862	0.0056
$t_2 = \bar{t}_2 + \tau_2 s_2^*$				0.0211	-0.1901
q_2				0.74	0.74

Table 9: Taxes calibration implementing the first best for the US with $\beta = 0.4$, $\gamma = 0.0006$, $c = 0.0231$, $b = 0.0430$. Sugar content is in g/ℓ, prices and taxes are in €/ℓ.

	First best	Monopoly	First Best	Duopoly	Collusion
s_1	22.11	22.11	13.27	13.22	13.27
s_2			26.53	27.18	26.53
θ_{p1}	0.0297	0.0364	0.0271	0.0306	0.035
θ_{p2}			0.0350	0.0374	0.039
% mkt_1	0.31	0.15	0.31	0.159	0.093
% mkt_2			0.31	0.129	0.093
q_1		0.66		0.35	0.41
q_2				0.71	0.77
Taxes implementing the first-best solutions					
$\bar{t}_1$		-0.1467		-0.781	-0.0528
τ_1		-0.0066		0.0549	-0.0119
$t_1 = \bar{t}_1 + \tau_1 s_1^*$		-0.293		-0.053	-0.211
q_1		0.51		0.31	0.31
$\bar{t}_2$				-1.774	-0.2112
τ_2				0.0629	-0.0040
$t_2 = \bar{t}_2 + \tau_2 s_2^*$				-0.106	-0.3168
q_2				0.61	0.61

Table 10: Taxes calibration implementing the first best for the US if there is no misperception: $\beta = 1$, and for $\gamma = 0.0006$, $c = 0.0231$, $b = 0.0430$. Sugar content is in g/ℓ, prices and taxes are in €$/\ell$.

References

[1] Allcott, H., Mullainathan, S., and Taubinsky, D. (2014). Externalities, Internalities, and the Targeting of Energy Policy. Journal of Public Economics, Vol. 112 (April) 72–88.

[2] Allcott, H., Lockwood, B., and Taubinsky, D. (2019 a). Should We Tax Soda? An Overview of Theory and Evidence. Journal of Economic Perspectives, 33, No. 3, pp. 202-27.

[3] Allcott, H., Lockwood, B., and Taubinsky, D. (2019 b). Regressive Sin Taxes, with an Application to the Optimal Soda Tax, The Quarterly Journal of Economics, 134 (3), 1557–1626.

[4] Afshin A., Penalvo JL., Del Gobbo L., et al. (2017). The prospective impact of food pricing on improving dietary consumption: a systematic review and meta-analysis. PLoS One, 12(3):e0172277.

[5] Barahona, N., Otero, C. and Otero, S. (2023). Equilibrium Effects of Food Labeling Policies. Econometrica, 91: 839–868.

[6] Bernheim, B.D., and Taubinsky, D.(2018). Behavioral Public Economics. in Handbook of Behavioral Economics – Foundations and Applications 1, B. Douglas Bernheim, Stefano DellaVigna, and David Laibson (eds), Chapter 5, Elsevier, 2018, pp. 381-516.

[7] Bollinger, B., Leslie, P., and Sorensen, A. (2011). Calorie Posting in Chain Restaurants. American Economic Journal: Economic Policy, 3 (1): 91–128.

[8] Bonnet, C. and Réquillart, V. (2013). Tax incidence with strategic firms in the soft drink market. Journal of Public Economics, 106, 77–88

[9] Cornelsen, L. and Carreido, A. (2015). Health-related Taxes on Food and Beverages. Food Research Collaboration Policy Brief.

[10] Cremer, H., De Donder, P., Maldonado, D., Pestieau, P. (2012). Taxing sin goods and subsidizing health care. The Scandinavian Journal of Economics 114 (1), 101–123.

[11] Cremer, H., Goulão, C. and Roeder, K. (2016). Earmarking and the political support of fat taxes. Journal of Health Economics, 50, 258–267.

[12] Devaux, M., Sassi, F., Church, J., Cecchini, M.and Borgonovi, F. (2011). Exploring the Relationship Between Education and Obesity. OECD Journal: Economic Studies 2011/1, 121–159.

[13] Dubois, P., R. Griffith and M. O'Connell (2020). How well targeted are soda taxes? American Economic Review, 110 (11)

[14] Fullerton, D., and West, S. (2002). Can Taxes on Cars and on Gasoline Mimic an Unavailable Tax on Emissions? Journal of Environmental Economics and Management, 43 (1), 135–157.

[15] Fullerton, D., and West, S. (2010). Tax and Subsidy Combinations for the Control of Car Pollution. The B.E. Journal of Economic Analysis and Policy, vol. 10, no. 1.

[16] Goulão, C. and Pérez-Barahona, A. (2014). Intergenerational transmission of non-communicable chronic diseases, Journal of Public Economic Theory, vol. 16, n3, 467–490.

[17] Gruber, J., and Koszegi, B. (2004). Tax Incidence When Individuals are Time Inconsistent: The Case of Cigarette Excise Taxes, Journal of Public Economics, 88, 9–10, 1959–1987.

[18] Grummon, A.H., Smith, N.R., Frerichs, L., Golden, S.D., Taillie, L.S., and Brewer, N.T. (2019). Health warnings on sugar-sweetened beverages: Simulation of impacts on diet and obesity among U.S. adults. American Journal of Preventive Medicine, 57(6): 765-774.

[19] Haavio, M. and Kotakorpi K. (2011). The political economy of sin taxes. European Economic Review 55, 575–594.

[20] Hamilton, S. F., and Réquillart, V. (2017). Market Competition and the Health Composition of Manufactured Food. Health Economics 26(12), 1637-1643.

[21] Innes, R. (1996). Regulating Automobile Pollution Under Certainty, Competition and Imperfect Information. Journal of Environmental Economics and Management 31 (2), 219–239.

[22] Kotakorpi, K. (2008). The Incidence of Sin Taxes. Economics Letters 98, 95–99.

[23] Mussa, M. and Rosen, S. (1978). Monopoly and Product Quality. Journal of Economic Theory 18, 301–317.

[24] O'Connell, M. and Smith, K. (2024). Optimal sin taxation and market power. American Economic Journal: Applied Economics, forthcoming.

[25] O'Donoghue, T., and Rabin, M. (2006). Optimal sin taxes. Journal of Public Economics, 90, 10, 1825–1849.

[26] Sadoff, S., Samek, A. and Sprenger, C. (2020). Dynamic Inconsistency in Food Choice: Experimental Evidence from Two Food Deserts, Review of Economic Studies, 87: 1954–1988.

[27] Spence, A. (1975). Monopoly, Quality, and Regulation. The Bell Journal of Economics 6(2), 417–429.

[28] Varian, H. (1992). Microeconomics Analysis. W. W. Norton & Company, Inc. New York.

[29] WHO (2018). Noncommunicable diseases country profiles 2018. Geneva: World Health Organization; 2018.

[30] WHO(2023). Global report on the use of sugar-sweetened beverage taxes, 2023. Geneva: World Health Organization; 2023. Licence: CC BY-NC-SA 3.0 IGO.

[31] Wilde, P., Huang, Y., Sy,S., Abrahams-Gessel, S., Veiga Jardim, T., Paarlberg, R., Mozaffarian, D., Micha, R., and Gaziano, T. (2019). Cost-Effectiveness of a US National Sugar-Sweetened Beverage Tax With a Multistakeholder Approach: Who Pays and Who Benefits. American Journal of Public Health 109, 276–284.