WORKING PAPERS

N° TSE - 992

February 2019

"Soda tax incidence and design under monopoly"

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Soda tax incidence and design under monopoly[1]

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February 1, 2019

[1]We thank 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 the Chaire "*Marché des risques et creation de valeur*" of the FdR/SCOR is gratefully acknowledged.

Abstract

We consider an unhealthy good, such as a sugar-sweetened beverage, the health damages of which are misperceived by consumers. The sugar content is endogenous. We first study the solution under "pseudo" perfect competition. In that case a simple Pigouvian tax levied per unit of output but proportional to the sugar content is sufficient to achieve a first best solution. Then we consider a monopoly. 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. Interestingly, both the total tax as well as its sugar component can be positive as well as negative.

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

1 Introduction

In 2016, 40% of the world's population was overweight. More than 60% of the American and European populations were overweight, with 28% and 23% obese, respectively.[1] Being overweight or obese constitutes a major risk factor for non-communicable chronic diseases, such as diabetes, cancer or cardiovascular conditions, which represent the major cause of death worldwide; WHO (2018).

A possible explanation for the excess consumption of unhealthy goods is that individuals misperceive the adverse health effects of these goods in the long run. Alternatively, individuals may be subject to problems of self-control in their consumption (see, among others, 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 either case, 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 effects 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. Soda taxes imposed on sugar-sweetened beverages (SSB) are already used in several countries, and are under consideration in many others. Preliminary evidence from existing taxes on food and beverages suggests that soda taxes have been effective in reducing purchases but the long-run effects on health are the subject of debate; see Cornelsen and Carreido (2015). 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, adopt specific taxes per liter or ounce. The United Arab Emirates, on the other hand, apply an *ad valorem* tax of 50% on SSB, and recently the UK opted for a two-level specific tax depending on the sugar content.

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?

[1] 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 November 8, 2018.

One concern in the debate about the effectiveness of fat or soda taxes is that retailers might absorb the tax rather than passing it on to customers, thereby obscuring the signal that governments are trying to send. This in turn is an issue of tax incidence, which is well understood under perfect competition, where it is essentially a matter of demand and supply elasticities. However, most markets for SSBs are imperfectly competitive. Furthermore, 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). In this context, the issue of tax incidence is more complex and the appropriate design of taxes has to be amended accordingly.

We illustrate this point by considering the simplest form of imperfect competition namely a monopoly. For simplicity of exposition, we concentrate on SSBs and their sugar content, but our analysis also applies to fatty goods, for instance. 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. Interestingly, both the total tax as well as its sugar component can be positive as well as negative.

2 Setup

Individuals consume x units of an unhealthy good (soda) of sugar content s and a numeraire good y. Their exogenous income is equal to m. Their true utility function is given by:

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

where $u(x, s)$ reflects the short-term utility from the consumption of the unhealthy good. 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".

In the long run, higher 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 $h(S) = h(xs)$ with $\partial h(S)/\partial x > 0$, $\partial h(S)/\partial s > 0$ and $\partial^2 h(S)/\partial s^2 > 0$. The health effects of unhealthy eating tend to occur later in life and the full understanding of their occurence is difficult. Thus individuals may not perceive fully these negative health effects (see Devaux et al., 2011, among others). Their perceived harm function is given by $\beta h(xs)$, where $\beta \in]0, 1]$ so that their perceived utility is given by:

$$\hat{U} = u(x, s) + y - \beta h(xs). \tag{2}$$

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:

$$q(x, s; \beta) = \frac{\partial u(x, s)}{\partial x} - \beta \frac{\partial h(S)}{\partial S} s. \tag{3}$$

Equation (3) 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:

$$q(x, s; \beta) = q(x, s; 1) + (1 - \beta) \frac{\partial h(S)}{\partial S} s. \tag{4}$$

3 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:

$$\frac{\partial u(x^*, s^*)}{\partial x} - \frac{\partial h(S^*)}{\partial S} s^* = \frac{\partial C(x^*, s^*)}{\partial x}, \tag{5}$$

$$\frac{\partial u(x^*, s^*)}{\partial s} - \frac{\partial h(S^*)}{\partial S} x^* = \frac{\partial C(x^*, s^*)}{\partial s}, \tag{6}$$

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

4 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:

$$\widetilde{p}(s^c) = \frac{\partial C(x^c, s^c)}{\partial x}, \tag{7}$$

$$x^c \frac{\partial \widetilde{p}(s^c)}{\partial s} = \frac{\partial C(x^c, s^c)}{\partial s}. \tag{8}$$

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:

$$\frac{\partial u(x^c, s^c)}{\partial x} - \widetilde{q}(s^c) - \beta \frac{\partial h(S^c)}{\partial S} s^c = 0, \tag{9}$$

$$\frac{\partial u(x^c, s^c)}{\partial s} - x^c \frac{\partial \widetilde{q}(s^c)}{\partial s} - \beta \frac{\partial h(S^c)}{\partial S} x^c = 0. \tag{10}$$

The decentralization of the first best solution requires that (7)–(8) and (9)–(10) are satisfied by (x^*, s^*) as defined by (5)–(6). 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:

$$\widetilde{q}(s)x = [\widetilde{p}(s) + \tau s]x. \tag{11}$$

Departing from (9) and using (5), (7), and (11), 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 (8) and (10) 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.

5 Monopoly

5.1 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 (4) 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:

$$q(x,s;\beta)x = \left[p(x,s;\beta) + \bar{t} + \tau s\right] x. \tag{12}$$

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

$$q(x^m, s^m;\beta) - \bar{t} - \tau s + \frac{\partial q(x^m, s^m;\beta)}{\partial x} x^m = \frac{\partial C(x^m, s^m)}{\partial x}, \tag{13}$$

$$\left(\frac{\partial q(x^m, s^m;\beta)}{\partial s} - \tau\right) x^m = \frac{\partial C(x^m, s^m)}{\partial s}. \tag{14}$$

5.2 Decentralization of the first best

The decentralization of the first best solution requires that equations (13)–(14) and the consumer FOCs, are satisfied by (x^*, s^*). Departing from (5) and (6), and using (13) and (14), 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:

$$t = \bar{t} + \tau s = q(x^*, s^*; \beta) + \frac{\partial q(x^*, s^*)}{\partial x} x^* - \frac{\partial u(x^*, s^*)}{\partial x} + \frac{\partial h(S^*)}{\partial S}, \tag{15}$$

$$\tau = \frac{\partial q(x^*, s^*; \beta)}{\partial s} - \left[\frac{\frac{\partial u(x^*, s^*)}{\partial s}}{x^*} - \frac{\partial h(S^*)}{\partial S} \right]. \tag{16}$$

Differentiating inverse demand defined by (4) 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 (15)–(16), respectively, yields:

$$t = \bar{t} + \tau s^* = \frac{\partial q(x^*, s^*; \beta)}{\partial x} x^* + (1 - \beta) \frac{\partial h(S^*)}{\partial S}, \tag{17}$$

$$\tau = \left\{ \frac{\partial q(x^*, s^*; 1)}{\partial s} - \frac{\left[\frac{\partial u(x^*, s^*)}{\partial s} - x^* \frac{\partial h(S^*)}{\partial S} \right]}{x^*} \right\} + (1 - \beta) \left[\frac{\partial h(S^*)}{\partial S} + \frac{\partial h^2(S^*)}{\partial S^2} s^* x^* \right]. \tag{18}$$

Expression (17) 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. 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 (18), recall that absent of misperception one can simply think of s as "quality", except that unlike in traditional models our 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.[2] 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 6.

The second term is the Pigouvian term which vanishes when $\beta = 1$. Otherwise it is positive.

Expressions (17) and (18) 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.

6 Example

Population size is normalized to one. Consumers may buy a unit of soda or none at all. Their perceived utility (2) is given by:

$$\hat{U} = \theta s + m - q - \beta h(s), \tag{19}$$

when consuming one unit of soda with sugar content s and $\hat{U} = m$ otherwise. The true utility is $U = \theta s + m - q - h(s)$ when consuming one unit of soda and $U = m$ otherwise. Consumers differ in θ, which is uniformly distributed over the interval $[a, a+1] \in \mathbb{R}^+$. For the sake of illustration we assume $h(s) = (1/2)\, s^2$. Let θ_p denote the marginal consumer indifferent between consuming one unit or none at all. It is defined by the level of θ_p that satisfies:

$$\theta_p(q, s; \beta) = (q + \beta h(s)/s)\,. \tag{20}$$

To reduce the number of cases we assume throughout this section that $a \leq 2 + c$, which, as will become clear below, ensures that absent of any taxes or subsidies the market is not fully covered in the monopoly solution.[3] Demand for the unhealthy good is then given by:

$$x\,(q, s; \beta) = a + 1 - \max[a, \theta_p(q, s; \beta)]. \tag{21}$$

[2] In other words, the sign first term in (18) may depend on the level of x. This is determined by the properties of the demand function.

[3] To be more precise, it ensures that the monopoly solution is interior. When $a = 2 + c$, the market *is* fully covered but the solution continues to be interior.

	a	s	q	x
Monopoly	$-$	$\frac{2(a+1-c)}{3\beta}$	$\frac{2(a+1-c)(a+1+2c)}{9\beta}$	$\frac{a+1-c}{3}$
First Best	$a \leq \frac{1}{2}+c$	$\frac{2(a+1-c)}{3}$	$-$	$\frac{2(a+1-c)}{3}$
	$a > \frac{1}{2}+c$	$\frac{1}{2}+a-c$	$-$	1

Table 1: Monopoly solution without taxes and first best for $a \leq 2+c$

Note that our example uses a setting where individual demand is discrete (0 or 1), but where consumers are heterogenous. Since preferences are quasi-linear this yields an aggregate demand (and welfare) which is perfectly consistent with the representative consumer approach used in the theoretical part.[4]

The good is supplied by a monopoly with a linear technology; per unit production costs are constant in quantity and given by $c(s) = cs$. The monopoly price p is given by the consumer price q adjusted by taxes or subsidies. Using demand $x\left(q, s; \beta\right)$ as given by (21), the monopoly solves:

$$\{q^m, s^m\} = \arg\max\left\{\left(q - \bar{t} - \tau s - c\left(s\right)\right) x\left(q, s; \beta\right)\right\}. \qquad (22)$$

To determine the first best solution, we set the consumer price equal to marginal cost (with respect to quantity) and substitute q by $c\left(s\right)$ in (20). The first best level of sugar is then given by:

$$s^* = \arg\max_s W = \int_a^{\theta_p(c(s),s;1)} m d\theta + \int_{\theta_p(c(s),s;1)}^{a+1} \left(m - c\left(s\right) + \theta s - h\left(s\right)\right) d\theta. \qquad (23)$$

Solving (22) and (23) for $h(s) = (1/2)\, s^2$ and $c(s) = cs$, using (20) and (21) 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 highlights the effects already identified in the general model. Two cases have to be considered in our example. First, when $a < 1/2 + c$, we have $x^m < x^* < 1$, and $s^* < s^m$. The market is partially covered both in the monopoly and first best solutions. The support of the taste parameter is not large enough to have the full market covered both under monopoly and in the first best solution. As expected, the first best solution implies a larger output, but the monopoly is choosing an excessive sugar content. In other words, the monopoly is under-providing quantity and over-providing sugar content. Second, when $a > 1/2 + c$, we have $x^m < x^* = 1$ and $s^* \lesseqqgtr s^m$ if and only

[4] See for instance Varian (1992), Section 9.4.

a	$\bar{t}$	τ	t
$a \leq \frac{1}{2}+c$	$\frac{2(a+1-c)^2(\beta-2)}{9}$	$\frac{(a+1-c)(1-2\beta)}{3}$	$-\frac{2(a+1-c)^2(1+\beta)}{9}$
$a > \frac{1}{2}+c$	$\frac{(1+2(a-c))[\beta(1+2(a-c))-4]}{8}$	$a-c-\beta\left(\frac{1}{2}+a-c\right)$	$-\frac{(4+2(a-c)(\beta-2)+\beta)}{8}$

Table 2: Taxes implementing the first best for $a \leq 2+c$

if $\beta \lesseqqgtr (a+1-3c)/3(2a+1-2c)$. In this case, the support of the taste for sugar parameter is large enough and the market is fully covered in the first best. The monopoly continues to under-provide quantity with respect to the first best. In contrast, the monopoly can be under-providing or over-providing sugar, and this mainly depends on the level of misperception. If misperception is large enough (low β), the monopoly is over-providing sugar. If, on the other hand, misperception is low (high β), the monopoly is under-providing sugar.

The first best can be decentralized through an affine per unit tax $t = \bar{t} + \tau s$, described in Table 2. Consider first the case where $a \leq 1/2 + c$, where the first best and the monopoly solution involve partial market coverage. As the monopoly is under-providing quantity, the consumer price has to decrease so that the total per unit tax t is negative for all levels of β. More interestingly, we obtain that even though $s^* < s^m$, the sugar content is subsidized when misperception is low enough; more precisely, we have $\tau < 0$ if and only if $\beta > 1/2$. This is because given the first best output level (induced by the negative t), the monopoly would tend to decrease its demand by lowering the level of sugar s under its first best value. In this case, the monopoly term in (18) pleads for a negative τ while the Pigouvian term goes of course in the opposite direction. When misperception is not too large, the monopoly term dominates and sugar content has to be subsidized.

When the lowest level of θ is sufficiently large ($a > 1/2 + c$), the first best solution implies full market coverage. Several cases can arise depending on the parameter values, and describing all of them would be tedious. For the sake of illustration, we therefore concentrate on the situation where $a \in [1/2 + c, 3/2 + c]$; that is, the parameter is larger than the benchmark considered in Table 2 but not too large. The expression in Table 2 then shows that $\bar{t} < 0$ and $\tau > 0$. The relative strength of each instrument depends again on misperception and the overall per unit tax may be positive or negative. If misperception is high enough – that is, $\beta < 4(a-c-1)/[2(a-c)+1]$ – the sugar content effect "dominates" and $t > 0$. Otherwise, the market coverage effect "dominates" and $t < 0$.

7 Conclusion

In a recent policy oriented survey, Allcoot et al. (2019) advocate to "tax grams of sugar, not ounces of soda". We show that taxing sugar is indeed *necessary* but may not be *sufficient* to restore optimality. To be more precise, Allcoot et al. (2019)'s recommendation is applicable under perfect competition. However, even there it must be interpreted with care: the appropriate tax is proportional to the sugar content but it will be passed on, at least in part, to consumers. Consequently, the ounces of soda are effectively *also* taxed.

Under imperfect competition with endogenous product characteristic, the appropriate tax rule is more complex. We have illustrated this point by considering the simplest form of imperfect competition; namely a monopoly. 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 "ounces of soda" must also be taxed, and that this tax is in part independent of the 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. 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 chosen application, it must be remembered that nutritional policies should account for the global effects on the whole diet, accounting for substitution and complementary effects across final and intermediate goods. These issues are left for future research.

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