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Not so sweet: impacts of a soda tax on producers

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Abstract
Portugal introduced a sugar-sweetened beverages (SSB) tax in 2017. This study uses unique administrative accounting data for all SSB producers/importers in Portugal, and an event study design with bottled water firms as the primary comparison group, to assess the causal impacts of the tax on multiple firm-level outcomes. We find a 6.8% average decrease in domestic SSB sales, relative to bottled water. The soda tax hindered SSB firms' financial health, namely net income, ability to convert receivables into cash, and liabilities. SSB producers/importers did not decrease wages, cut jobs, or modify their workforce toward higher R&D capacity. Forgone corporate income tax appears negligible compared to the government revenue generated by the tax itself.

Keywords Sugar-sweetened beverages tax · Soda sales · Soda manufacturers · Firm-level outcomes · Industry responses · Event study

JEL classifications H25 · L20 · L66

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1 Introduction

In 2016, the World Health Organization (WHO) urged policy makers to tax sugar-sweetened beverages (SSB, or soda, for short), motivated by the evident link between soda consumption and major diseases such as obesity and type 2 diabetes, and by growing evidence on the effectiveness of soda taxes for curbing sugar intake from soda (WHO, 2016). As of May 2022, more than 60 jurisdictions around the world had already implemented soda taxes (Global Food Research Program UNC, 2022). Concomitantly, the literature on the impacts of soda taxes has grown substantially, focusing almost exclusively on demand-side impacts (Cawley et al., 2019b).

This study follows a complementary perspective by focusing on a supply-side research question: what kind of a burden are we imposing on the industry when a government adopts a soda tax? To answer this, we document the impacts of the Portuguese soda tax, introduced in 2017, on a set of firm-level outcomes of soda producers and importers, including for example sales, employment, and profits. We rely on a very rich administrative dataset that contains yearly accounting information from the profit and loss (P&L) statement and the balance sheet, as well as workforce-related information, for the universe of SSB producers and importers in Portugal, from 2012 to 2019. To estimate the causal impacts of the tax, we employ event studies and difference-in-differences models, using water bottling firms as primary comparison group.

We find a 6.8% average decrease in domestic SSB sales, relative to the comparison group of bottled water, and no effects on exports. The soda tax hindered SSB firms' financial health, namely net income, ability to convert receivables into cash, and liabilities. SSB producers/importers did not decrease wages or cut employment. Forgone corporate income tax revenues for the state appear negligible when compared with the revenue generated by the new tax itself.

We make four main contributions to the literature on SSB taxes. First, by analyzing domestic sales of the universe of SSB producers/importers, we provide evidence on the impacts of soda taxes on total consumption (i.e., in- as well as out-of-home consumption). Almost all previous studies rely on store-level sales data (Castelló & Casasnovas, 2020; Dickson et al., 2021; Gonçalves & Pereira dos Santos, 2020; Seiler et al., 2021; Taylor et al., 2019) or consumer-level supermarket purchases data (Aguilar et al., 2021; Bollinger & Sexton, 2023; Capacci et al., 2019; Cawley et al., 2019a; Cawley et al., 2020; Colchero et al., 2016; Fearne et al., 2019; Fichera et al., 2021; Léger & Powell, 2021; Leider & Powell, 2022; Nakamura et al., 2018; Rojas & Wang, 2021; Silver et al., 2017), from one or more retailers. Other outlets like wholesalers, restaurants and bars, or vending machines—put differently, out-of-home soda consumption—have largely been ignored (Cornelsen & Smith, 2018). However, in-home and out-of-home soda consumption can potentially respond very differently to soda taxes. For instance, out-of-home consumption could be less responsive to the soda tax due to a more inelastic demand or because of lower pass-through to consumer prices (Law et al., 2022). The fewer studies that are not limited to retail sales either rely on survey data on all purchases/soda intake (Cawley et al., 2022; Colchero et al., 2017) or use macro-level data, relying solely on time

variations (Alsukait et al., 2020; Arteaga et al., 2021). Overall, most studies find that soda taxes reduce SSB consumption (95% confidence interval (CI) from a meta-analysis by Andreyeva et al. (2022): 9%–20% reduction in SSB sales), including in Portugal (Gonçalves & Pereira dos Santos, 2020). The estimated reductions vary in size, depending on study setting and methodology, as well as consumer income, age, and baseline consumption level (Allcott et al., 2019b; Colchero et al., 2015; Dubois et al., 2020; Sharma et al., 2014).

The second main contribution is that we indirectly explore manufacturers' reformulation activity, by looking at changes in the firms' workforce, namely the number of employees working in research and development (R&D). This contribution relates to the specific design of the Portuguese soda tax, the first multi-tier soda tax in the world. The tax is levied on producers/importers and is structured in several brackets, based on drinks' sugar content. This multi-tier design appears to have incentivized soda producers to reformulate recipes toward lower sugar content.[1] Recipe reformulation is a main channel through which multi-tier soda taxes can reduce sugar intake from soda, besides reducing soda consumption. Studies show that taxes designed in this way (i.e., tax rates that vary according to a specific characteristic of the good, like sugar) incentivize new "tax preferred" product introduction and innovation by manufacturers (Gillitzer et al., 2017; McCullough, 2018). Studies also show the superiority of multi-rate soda taxes in terms of welfare (O'Connell & Smith, 2021) and economic and public health gains (Grummon et al., 2019). Since Portugal implemented its soda tax in 2017 and reports of reformulation and reductions in soda consumption started to emerge, other countries were motivated to (re)design their soda taxes in a similar manner, e.g., France, Ireland, the UK. If substantial reformulation activity was going on around the time the tax was implemented, then we expect to find a positive impact of the Portuguese soda tax on the number of employees working in R&D, and potentially higher average wages. The only study, to date, that directly explores the effects of a soda tax on reformulation is Dickson et al. (2021). The authors estimate that the UK soda tax reduced calorie intake from soda by around 6,500 cal per annum per resident, with more than 80% of that reduction attributable to manufacturers' reformulation activities.

The third main contribution is that we consider the impacts of a soda tax for economic agents that have been largely overlooked in this literature, namely producers/importers and, indirectly, workers. Similarly to other countries, in Portugal, the soda tax is levied on producers/importers. Producers/importers can adjust to the new tax along two main margins. The first is specific to the case of multi-tier taxes, like the Portuguese one: producers may reduce the sugar content of their drinks to pay a lower tax. This option is limited by consumer preferences, because if consumers dislike the new recipe, they will stop buying. Reformulation also entails costs, with R&D, relabeling, rebranding, as well as renegotiations with retailers and other

[1] According to industry data, Portuguese manufacturers reduced the sugar content of some drinks, even though this was an ongoing trend even before the tax was introduced. The change in the caloric content per 100 ml of non-alcoholic beverages sold in Portugal was − 11% from 2016 to 2017 (Goiana-da-Silva et al., 2020; Grupo de Trabalho, 2018).

clients. As stated above, there is evidence of reformulation activity following Portugal's and UK's soda taxes. The second main margin of adjustment is changing prices: producers/importers must decide how much of the tax to absorb, and how much to pass on to retailers, wholesalers, restaurants, and other clients. This will depend on multiple factors, such as the relative market power of each agent, price elasticity of demand, and firms' drinks portfolio.[2] All available evidence on soda tax pass-through pertains to overall shifts to final consumer prices (Aguilar et al., 2021; Alsukait et al., 2020; Berardi et al., 2016; Bollinger & Sexton, 2018; Capacci et al., 2019; Cawley & Frisvold, 2017; Cawley et al., 2018a; Cawley et al., 2018b; Dickson et al., 2021; Etilé et al., 2018; Gonçalves & Pereira dos Santos, 2020; Grogger, 2017; Léger & Powell, 2021; Leider & Powell, 2022; Rojas & Wang, 2021; Seiler et al., 2021; Silver et al., 2017; Stacey et al., 2019). Pass-through to consumer prices is usually large (95% CI from a meta-analysis by Andreyeva et al. (2022): price increases of 6.6%–9.8% for a 10% equivalent SSB tax); however, it is unclear how much of it is attributable to producers/importers, and how much to retailers.[3] Overall, few studies have considered the impacts of soda taxes for SSB producers/importers and workers, who must deal with changing prices, higher salience on the health effects of sugar-sweetened beverages leading to new consumption patterns, as well as to adapt to the tax through product innovation and reformulation. Using time series data, Law et al., (2020a, 2020b) find short-lived negative impacts of the UK soda tax on stock returns and domestic turnover of UK soda manufacturers. Guerrero-López et al. (2017) and Lawman et al. (2019) find no aggregate unemployment effects of soda taxes in Mexico and Philadelphia. In this paper, we consider firms' "financial health," which we assess based on net income (an indicator of profitability: the difference between total revenues and total expenses), and cash, receivables, and liabilities (which together provide insights on liquidity and solvency), as well as employment and wages.

The fourth and last main contribution is an estimation of the impact of the soda tax on corporate income tax payments. This is a relevant outcome from a government revenue perspective, as forgone corporate income taxes may partly offset the additional revenue from the soda tax.

To sum up, the literature on SSB taxes is extensive, but still has some gaps (see also Allcott et al., 2019a; Andreyeva et al., 2022; and Cawley et al., 2019b for recent reviews). Specifically, evidence on the impacts of soda taxes on consumption is mostly limited to in-home consumption, as most studies use data covering only retail sales. Other agents besides consumers and retailers, like producers, importers, and workers, have received little attention. With this study, we contribute with evidence on the impacts of soda taxes for producers/importers and their workforce and

[2] Agrawal and Hoyt (2019) discuss that empirical estimates of the pass-through may capture both direct and indirect (due to demand side linkages) effects of the tax on the market.

[3] There is evidence of full shifts of other taxes to consumer prices (Lyssiotou and Savva, 2021). Rozema (2018) studies the impact of taxes on cigarettes to understand how the burden of these taxes not borne by consumers is shared between upstream and downstream firms. Using Nielsen Homescan data, the author suggests that taxes are passed through to both wholesale and retail prices, with downstream firms bearing no more than one-third of the tax burden.

provide insights about total consumption effects (both in- and out-of-home), thanks to having data on domestic sales of the universe of soda producers and importers.

2 The Portuguese soda tax

The Portuguese soda tax was first mentioned in the Portuguese media on May 5, 2016, in the newspaper Expresso (2016). It received extensive media coverage until it was approved by the Parliament in December 2016 (Decree-Law no. 42/2016), and afterward, especially after it was implemented in February 2017. From the start, it was clear that the soda tax "was here to stay."

The soda tax is an excise tax on sugary drinks sold on Portuguese territory, regulated in the *Código dos Impostos Especiais de Consumo*. It is levied on producers and importers. The tax applies to non-alcoholic drinks with added sugar or sweeteners, including liquid or powder concentrates; drinks with 0.5–1.2% alcohol by volume are also taxed (e.g., mead, cider). Tax-exempt products include (1) milk-, soy-, or rice-based drinks, (2) fruit-, algae-, or veggie- based juice and nectar, as well as cereal- and nut-based drinks, and (3) drinks considered essential for special dietary needs.

Taxed drinks are grouped according to their sugar content in grams per liter, and different tax rates apply to each category (i.e., multi-tier tax). Initially, in 2017, there were two tiers, with the sugar threshold at 80 g per liter and the lower (upper) tier tax rate at about 8 (16) euro cents per liter. In 2018, both tax rates were slightly raised. In 2019, the lower tier was divided in three, further differentiating drinks according to the amount of sugar they contain. The two new lower tiers had their tax rate reduced, and the most sugary drinks (> 80 g of sugar per liter) had their tax rate aggravated. Since 2019, the tax rates are 1 euro cent per liter for drinks with less than 25 g of sugar per liter, 6 cents for drinks with 25 g or more and less than 50 g of sugar per liter, 8 cents for drinks with 50 g or more and less than 80 g of sugar per liter, and 20 cents for drinks with 80 g or more sugar per liter (Table 1). Different tax rates apply to concentrates in liquid or powder form. The usual 23% VAT adds up to the soda tax. For reference, in Portugal, comparably with the UK, for example, the tax rate on the most sugary drinks is fairly aligned with WHO's recommendation that soda taxes raise retail soda prices by at least 20% (WHO, 2016).

3 Data and descriptive statistics

We use rich administrative data from the Central Balance Sheet Harmonized Panel (CBHP), provided by *Banco de Portugal*, for the years 2012–2019. The data cover the entire private sector in Portugal and include information on firms' workforce, as well as accounting data from the balance sheet and the P&L statement. This dataset results from yearly compulsory tax declarations (*IES—Informação Empresarial Simplificada*) that are submitted electronically to the Portuguese Ministry of Finance. The Tax Authority then sends this information to the Institute of Registration and Notary Affairs (IRN) that is in charge of sending the files to *Banco de*

Table 1 Portuguese SSB tax rates over the years

Sugar content	2017	2018	2019
< 25 g/l	8.22 euro cents/l	8.34 euro cents/l	1 euro cent/l
> = 25 g/l, < 50 g/l			6 euro cents/l
> = 50 g/l, < 80 g/l			8 euro cents/l
> = 80 g/l	16.46 euro cents/l	16.69 euro cents/l	20 euro cents/l

g/L = grams per liter. Usual 23% VAT adds to the soda tax

Portugal, to implement several cross-checks with other administrative sources and assure the quality of the data.[4]

There are 19 SSB producers/importers and 27 producers/importers of bottled water[5] that we identify based on firms' main economic activity—i.e., the activity accounting for the largest share of turnover (i.e., sales of goods and services). In the Portuguese Classification of Economic Activities, Revision 3, the relevant codes are CAE 11072—manufacture of soda and other non-alcoholic beverages, and CAE 11071—bottling of spring and mineral water. This is the (near) universe of SSB and bottled water producers/importers in Portugal, all of which are private firms, not listed in the stock market.[6]

The 19 SSB firms constitute our treatment group, as they produce/import drinks subject to the soda tax, i.e., drinks with added sugar or sweeteners, including liquid or powder concentrates (Sect. 2). Each firm has a portfolio of drinks of different brands, potentially subject to different tax rates on account of sugar content, which unfortunately we do not observe. The 27 water bottling firms constitute our primary comparison group (for a similar approach, see Alsukait et al., 2020; Etilé et al., 2021; Gonçalves & Pereira dos Santos, 2020; Taylor et al., 2019). We believe that bottled water firms are a suitable comparison group, as the soda tax is unlikely to affect bottled water consumption or water bottling firms, especially in the context of Portugal, for two main reasons. First, the water bottling and SSB industries are very similar in terms of inputs (except for sugar) and cost structures (e.g., packaging, marketing, logistics). So, they are likely to be similarly impacted by other shocks and trends (e.g., substitution of plastic for more sustainable packaging). Second, the Portuguese bottled water market is highly fragmented, consisting of many firms/brands (DGEG, 2022). In our data, in 2015, mean market share of bottled water firms was 4% (maximum at 19%), while the mean market share of SSB firms was 9% (maximum at 61%). More importantly, the largest SSB firms have very low

[4] This dataset was used by other papers including, *inter alia*, Caliendo et al. (2020) and Muñoz (2023).

[5] The tax is levied on producers, firms importing soda to then bottle domestically, and firms importing already bottled soda. The latter category includes importing distributors/retailers. In the case of retailers (e.g., wholesalers, supermarkets), soda importation is unlikely to be their main economic activity, which means they are not included in our data.

[6] Coca-Cola bottler for most European countries is listed on the London Stock Exchange. For the Portuguese market, they contract with a private domestic firm in Portugal that is in our data.

market shares in the bottled water market, limiting strategic manipulation of prices, marketing, and other business aspects (Gonçalves & Pereira dos Santos, 2020). Several studies on the impacts of soda taxes in different jurisdictions (e.g., Philadelphia, France, Saudi Arabia) have found no substitution between soda and bottled water consumption (Alsukait et al., 2020; Capacci et al., 2019; Cawley et al., 2019a; Seiler et al., 2021), although two studies in Mexico and Berkeley suggest such substitution may have occurred (Colchero et al., 2017; Silver et al., 2017). In sensitivity analyses, we consider alternative comparison groups (Sect. 4.2.).

In total, our main analyses include 46 firms. The panel is unbalanced, as 5 (2) firms enter the treatment (comparison) group between 2012 and 2019, and 3 (0) firms exit the treatment (comparison) group during that period. We confirm our results on the balanced panel as a robustness check.[7]

Regarding the time dimension, we consider 2016 to be the first treatment year because the tax was first publicly discussed in the media early that year and approved by the Parliament in December (Sect. 2). Doing so enables us to consider any anticipation effects (Roth et al., 2023), as firms may have adapted aspects of their business (e.g., reformulation) and consumers may have changed their habits (e.g., stockpiling) before the tax was implemented in February 2017 (Taylor et al., 2019).

Descriptive statistics are given in Table 2, for all outcomes considered: domestic and exported sales, profits (proxied by net income), total income revenues, and total expenses, cash, receivables (money owed to the firm for goods/services delivered but not yet paid for by customers), and liabilities, number of employees working in R&D, total number of employees, and average wage, and finally, corporate income tax payments. They are calculated separately for SSB and bottled water firms, in the pre- (2012–15) and post-tax periods (2016–19). In Table 3 in the Appendix, we present the results of balance tests, comparing the means of the outcome variables for SSB and bottled water firms in 2015 (last year of the pre-treatment period). Results indicate that the two groups of firms are very similar.

4 Empirical strategy

4.1 Event study specification

To identify the causal effects of the soda tax on the various firm-level outcomes, we estimate a series of event studies, using the following specification:

$$y_{it} = \sum_{t=2012}^{2014} \beta_t SSB_i \times year_t + \sum_{t=2016}^{2019} \beta_t SSB_i \times year_t + \alpha_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where y_{it} denotes one of the outcomes considered (e.g., domestic sales), for firm i in year t, SSB_i denotes the treatment indicator, which is equal to one if the firm is

[7] Firms that entry and/ or leave are comparatively small—and therefore unlikely to dilute the market share of other firms in economically meaningful amounts.

Table 2 Descriptive statistics

	Bottled water firms (comparison)					SSB firms (treatment)				
	Obs	Mean	Std. Dev	Min	Max	Obs	Mean	Std. Dev	Min	Max
Pre-tax										
Domestic sales	96	7,570,468	8,984,236	0	32,200,000	48	30,600,000	68,400,000	0	233,000,000
Exported sales	96	195,539	411,316	0	2,851,476	48	8,638,491	21,500,000	0	79,900,000
Net income	96	346,882	2,653,941	− 5,088,466	11,400,000	48	473,910	3,539,913	− 7,839,936	14,800,000
Total income	96	8,752,184	10,300,000	0	38,600,000	48	42,300,000	96,400,000	0	320,000,000
Total expense	96	8,405,302	9,065,132	26,204	30,100,000	48	41,800,000	94,200,000	0	310,000,000
Cash	96	220,444	449,128	71	3,100,799	48	590,814	2,343,760	0	15,700,000
Receivables	96	1,646,639	1,955,405	0	9,828,467	48	7,348,327	15,900,000	0	64,300,000
Liabilities	96	12,100,000	22,100,000	8,095	123,000,000	48	38,400,000	109,000,000	86,272	412,000,000
Income tax	96	− 75,090	1,347,197	− 12,600,000	2,187,857	48	138,366	854,436	− 2,762,697	2,971,260
Average wage	96	13,013	5,573	0	31,010	48	13,035	10,189	0	62,251
# Employees	96	55	67	0	315	48	142	325	0	1,212
# Employees inR&D	34	0.18	0.46	0	2	18	2	5	0	13
Post-tax										
Domestic sales	99	8,739,701	10,700,000	0	48,200,000	54	32,100,000	76,700,000	0	260,000,000
Exported sales	99	150,200	259,005	0	968,772	54	5,271,218	10,800,000	0	39,000,000
Net income	99	1,109,984	3,393,949	− 2,133,503	15,900,000	54	939,923	2,971,643	− 1,092,650	13,000,000
Total income	99	10,200,000	12,400,000	0	55,900,000	54	39,100,000	90,600,000	0	317,000,000
Total expense	99	9,052,056	10,300,000	4,912	40,000,000	54	38,100,000	88,300,000	0	309,000,000
Cash	99	560,315	1,000,692	0	4,797,750	54	469,200	1,020,181	0	5,080,177
Receivables	99	1,594,349	2,182,461	0	14,800,000	54	11,200,000	23,300,000	0	82,700,000
Liabilities	99	9,655,651	16,500,000	1,437	89,000,000	54	36,000,000	105,000,000	2,776	404,000,000
Income tax	99	211,702	859,451	− 1,057,868	5,623,661	54	320,996	1,009,489	− 269,367	4,515,820

Table 2 (continued)

	Bottled water firms (comparison)					SSB firms (treatment)				
	Obs	Mean	Std. Dev	Min	Max	Obs	Mean	Std. Dev	Min	Max
Average wage	99	12,738	6,817	0	29,780	54	16,559	25,077	0	159,987
# Employees	99	53	68	0	333	54	130	330	0	1,264
# Employees in R&D	34	0.09	0.29	0	1	21	2	4	0	10

All variables measured in Euros, except for numbers of employees

a SSB producer/importer and zero if it is a bottled water firm, and $year_t$ are a set of year indicators. The coefficients of interest are the β_t, which give the average change in the outcome of SSB firms, compared to bottled water firms, between year t and 2015, the reference year (last year of the pre-treatment period). Lastly, α_i and γ_t are firm and year fixed effects, respectively, and ε_{it} is the random error term. The standard errors are clustered at the firm level (Bertrand et al., 2004).[8]

For comparison, we also estimate (static) difference-in-differences (DiD) models, following a specification similar to the one above, but with only one interaction term, between the treatment indicator, SSB_i, and a post-treatment indicator equal to one for years 2016–2019 and zero otherwise. We favor the event study specification because it allows us to test if the outcomes of SSB and bottled water firms follow similar patterns in the pre-tax period (see below), and it provides estimations of both short- and medium-run effects instead of an average effect over the entire post-tax period (Armstrong et al., 2023).

Our identification strategy relies on two assumptions: 1) no anticipation effects before the first media articles mentioning the tax, and 2) that each outcome would have followed a common trend for both SSB and bottled water firms, had the soda tax not been introduced (Roth et al., 2023). We can split the last assumption in two. First, the parallel trends assumption states that prior to the tax implementation, each outcome follows comparable trends for both SSB and bottled water firms. The event study design allows us to present comforting evidence that this assumption is likely to hold (Roth, 2022). Throughout the results section, we show the estimates of the β_t coefficients from Eq. (1) for the pre-treatment period, along with the 95% and 90% confidence intervals. For all outcomes, those estimates are small and not statistically different from zero, indicating that the parallel trends assumption holds. Second, the common shocks assumption states that other events occurring during or after the soda tax was introduced affect the outcomes of both groups of firms in a similar manner. The fact that the parallel trends assumption appears to hold, combined with the great similarity between the SSB and water bottling industries (Sect. 3), makes the common shocks assumption reasonable. We are not aware of any relevant event occurring between 2016 and 2019, apart from the soda tax, that was likely to affect only one of the two industries.

4.2 Empirical challenges and robustness checks

To cope with the right skewness of most outcome variables, we use the inverse hyperbolic sine (IHS) transformation. This transformation is increasingly popular among econometricians as it allows to retain nonpositive values for the analyses, as opposed to a log transformation, for which nonpositive values are not defined (Bellemare & Wichman, 2020). The IHS transformation depends on the scale of the variables: for large numbers, the transformation is close to a natural log transformation,

[8] Prices within sectors of activity tend to be correlated because they face similar shocks (Cameron and Miller, 2015). Clustering standard errors by sector would, however, "overfit" the estimated residuals. This is similar to the problems faced by, *inter alia*, Cawley and Frisvold (2017), Harju et al. (2018), and Cotropia and Rozema (2018).

while for small magnitudes, it almost does not modify the variable. Following Aïhounton and Henningsen (2019), we multiply each outcome variable by a scaling factor. No matter the scaling factor, zero values remain zeros, but we can move the non-zero values "closer to" or "further away from" the zero values. For each variable, we test nine scaling factors: $10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}, 10^{0}, 10^{2}, 10^{4}, 10^{6}, and 10^{8}$. As advised by Aïhounton and Henningsen (2019), we use the within R^2 as a criterion to select the most suited scaling factor for each outcome variable. Bellemare and Wichman (2020) point out that one should not directly interpret IHS coefficient estimates as percent changes when the mean of the IHS-transformed outcome variable is below 10. Doing so could lead to over- or understatements of the effects' magnitudes. So, in addition to the coefficients, we report the retransformed marginal effects (i.e., marginal effects on the original scale of the dependent variable) based on the recent work of Norton (2022). As a robustness check, in the Appendix, we also present results when using the natural logarithm (ln) transformation, as well as a $\ln(y+1)$ transformation.

SSB and bottled water firms are identified based on their main economic activity, i.e., the activity accounting for the largest share of turnover (Sect. 3). Since the SSB and bottled water industries are arguably similar, it is possible that a firm's main activity is the manufacture/importation of SSB, but part of its turnover comes from bottled water, or vice versa. Such a firm would compromise the parallel trends assumption. We address this potential issue in three ways. First, we exclude from the analyses the only firm whose main economic activity switched from manufacture/importation of SSB to bottled water during the period of analysis (a small firm with only five workers). Importantly, the average share of turnover (sales of goods and services) generated by the main economic activity of the remaining 46 firms is 96.7%, and that share is below 90% for only four companies. Second, we conduct a robustness check where we drop those four firms that generate less than 90% of their turnover from their main economic activity. Lastly, we rely on the following reasoning. Since the soda tax rate is defined at the product level, while our data are at the firm level, and given that SSB firms produce more than one beverage, there is heterogeneity in treatment intensity within the treatment group. Depending on their product mix, some firms are more impacted by the soda tax than others (e.g., those producing the sweetest drinks).[9] In this context, the presence of a few firms in the treatment group that generate a small share of their turnover from bottled water merely "dilutes" the treatment effects, but does not harm our identification strategy.

We also seek to validate our main findings using alternative comparison groups, namely firms that produce/import (a) fruit juice, (b) milk (c) wine, and even (d) perfumes, cosmetics and hygiene products (CAE codes 10320, 10510, 1102, 20420). These are industries that share some features with the SSB industry (e.g., carton packages, glass or plastic bottles, logistics), albeit less than bottled water does.

Lastly, since the tax only applies to soda sold in Portugal, SSB firms that sell a larger share of their products in Portugal are more impacted by the soda tax than

[9] Unfortunately, we cannot use this variation given that our firm-level data are anonymized. Moreover, we do not know the product mix of each firm, and therefore, we cannot exploit border discontinuities among tax tiers to understand and analyze reformulation.

those that export a large part of their products. Based on this reasoning, we create a treatment intensity variable by dividing pre-treatment sales (in 2015) by total sales in the same year. By construction, a SSB firm exporting 40% of its sales has a treatment intensity of 0.6, while a SSB firm exporting all its products has a treatment intensity of 0—the same as a water bottling firm. We repeat the analyses using this treatment intensity variable instead of the binary treatment indicator.

5 Results

5.1 Domestic and exported sales

Figure 1 shows the estimated impacts of the soda tax on domestic and exported sales. Results indicate that domestic sales of SSB, relative to bottled water, decreased after the soda tax was implemented, and the effect exacerbates over the years. Considering the estimated marginal effect from the DiD specification, which gives the average impact over the entire treatment period, the introduction of the soda tax caused a EUR 2.1 million decrease in domestic sales per firm per year, which represents 6.8% of mean domestic sales among SSB firms in pre-treatment years (Tables 2 and 4). This estimated decrease in sales is closer to the lower range of estimates from the literature (as reported in the meta-analysis by Andreyeva et al., 2022). Since previous studies are mostly limited to retail sales, i.e., in-home consumption (Sect. 1), this may suggest that out-of-home consumption is less responsive to the soda tax (either due to a more inelastic demand or because of lower pass-through to consumer prices; Grupo de Trabalho, 2018).

Since only SSB sold on Portuguese territory are subject to the tax, exported sales are not expected to respond to the soda tax, which is what we find (results from the event study in Fig. 1 and DiD results in Table 4). Note that Portuguese soda firms are very much oriented toward the domestic market (exports represent 28% and 16% of sales in the pre- and post-treatment periods, respectively), and foreign markets did not necessarily become more attractive after the Portuguese soda tax was introduced, as soda taxes are common in European countries (e.g., Spain (Catalonia), France, and the UK). These precise zero results lend further credibility to the use of bottled water as the comparison group.

5.2 Firms' financial health and workforce

We find negative impacts of the soda tax on net income (total revenues minus total expenses) of SSB firms, compared to bottled water firms, statistically significant in 2016 ($p<0.1$), 2017 ($p<0.05$), and 2019 ($p<0.01$) (Fig. 2). Like with domestic sales, the negative impacts exacerbate over the years. However, results from the DiD specification are not statistically different from zero (Table 5). We also explore whether the event study result is driven by impacts on total revenues or total expenses, but lack of estimation precision precludes any conclusions (Roth, 2022).

The soda tax impacted negatively SSB firms' cash account, and positively their receivables account (Fig. 3). These effects are statistically significant in 2016 and

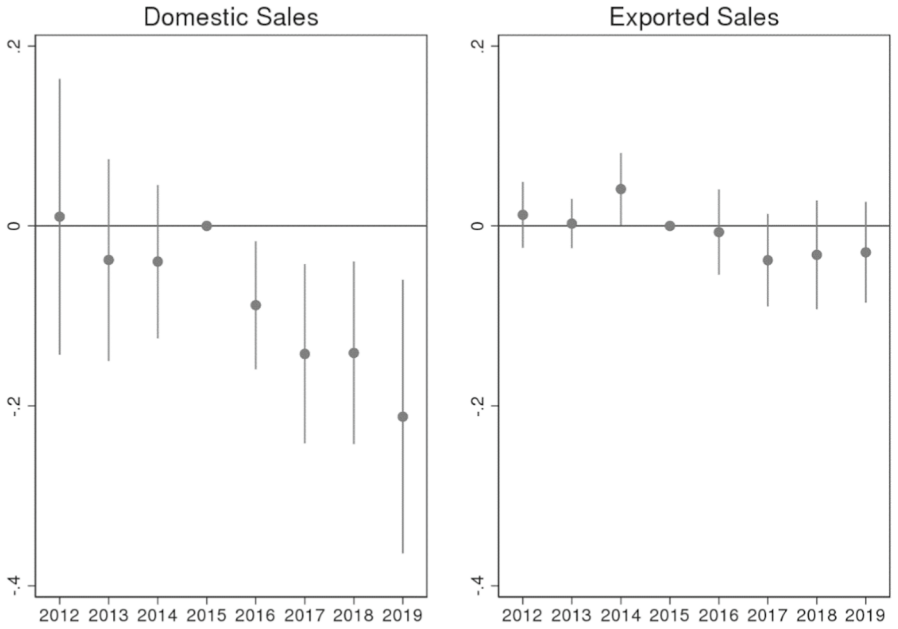

Fig. 1 Effects of the soda tax on domestic and exported sales. Notes: Coefficients from Eq. (1) along with the 90% confidence intervals using standard errors clustered at the firm level. Scaling factors: domestic sales*10^{-6}, exported sales*10^{-8}

2018 for cash, and in 2016, 2017, and 2018 for receivables ($p < 0.1$), but they are not statistically significant when considering all post-tax years together (DiD results in Table 6). Nevertheless, these results suggest that the tax may have hindered SSB firms' capacity to convert receivables into cash. A possible explanation is loss of negotiation power of manufacturers versus retailers and other clients that could translate into longer payment delays (Grupo de Trabalho, 2018). Furthermore, the soda tax significantly increased SSB firms' liabilities, compared to bottled water firms', starting in 2018 (Fig. 3). The estimated marginal effect from the DiD specification indicates an average increase in liabilities of EUR 8.5 million per firm per year, which represents 22% of mean liabilities among SSB firms in pre-treatment years (Tables 2 and 6). For instance, SSB firms may have had to contract debt to face costs associated with reformulation and relabeling, as well as early departure of products from shelves due to discontinuity (Grupo de Trabalho, 2018). Overall, the soda tax appears to have harmed SSB firms' financial health.

We do not find impacts of the soda tax on SSB firms' workforce, namely average wages, numbers of employees, or numbers of employees working in R&D (Fig. 4, Table 7). This suggests that reformulation activities (see Sect. 2) were undertaken without restructuring the employee base toward higher R&D capacity. It may be that firms had already built capacity to develop new recipes (industry reports suggest reformulation activities have been going on since before the tax was announced), or that firms outsource this activity. For example, multinational brands may develop new recipes in other countries. Despite the suggestive evidence that the soda tax

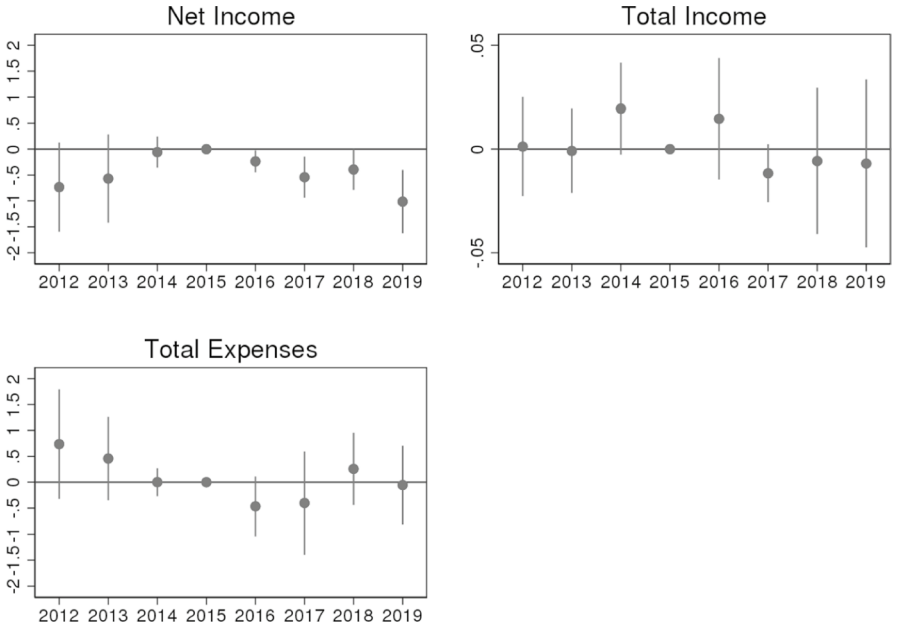

Fig. 2 Effects of the soda tax on net income, total income revenues, and total expenses. Notes: Coefficients from Eq. (1) along with the 90% confidence intervals using standard errors clustered at the firm level. Scaling factors: net income*10^{-6}, total income*10^{-2}, total expenses*10^{-2}

harmed firms' profitability (captured here by net income), in Portugal, firms face great hurdles to fire employees or decrease wages (Martins & Portugal, 2019), which may be one reason to explain why there are no impacts of the soda tax on employment or average wages.

5.3 Corporate income tax payments

Lastly, we find that starting in 2017, corporate income tax payments by SSB firms are significantly reduced by the soda tax (Fig. 5), though the reduction is economically small. In fact, considering the full post-tax period, the marginal effect from the DiD specification is statistically zero (Table 6). Official estimates from the Portuguese Ministry of Finance claim that the soda tax generated revenue of EUR 71.4, 72.5, and 60.1 million in 2017, 2018, and 2019, respectively. Hence, we conclude that the soda tax had a large positive impact on Portuguese public finances.[10]

[10] Taking the DiD point estimate at face value, a back-of-the-envelope calculation gives 210,735 euros of forgone corporate income tax over the period 2017–2019 (-4,683 euros times 45 SSB firm-year observations).

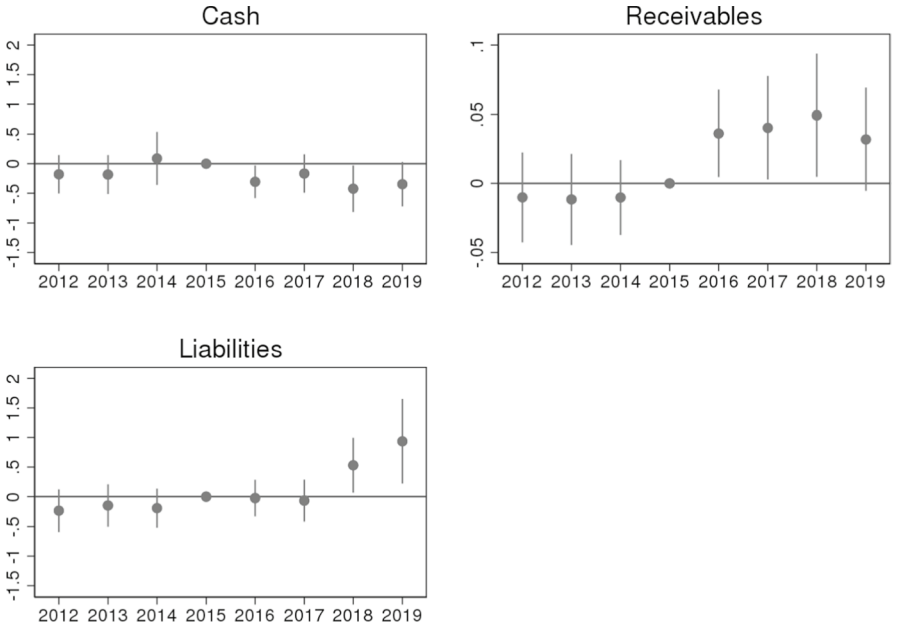

Fig. 3 Effects of the soda tax on cash, receivables, and liabilities. Notes: Coefficients from Eq. (1) along with the 90% confidence intervals using standard errors clustered at the firm level. Scaling factors: cash*10^{-6}, receivables*10^{-8}, liabilities*10^{0}

5.4 Robustness checks

Our baseline results are robust to a series of checks regarding potential outliers and our methodological decisions, namely (1) excluding extreme values of the outcome variables (1% winsorization), (2) dropping the largest firm of the dataset (a SSB producer that employs more than 1,000 employees and has turnover more than ten times larger than mean turnover), (3) dropping the four firms that generate less than 90% of their turnover from their main economic activity, (4) restricting the analyses to the balanced panel, (5) by excluding the year of 2016, after announcement but before tax implementation, and (6) using the ln(y) or ln(y + 1) transformation instead of the IHS transformation (Tables 8, 9 in the Appendix).[11]

In addition, we show that our baseline results do not depend on one specific comparison industry. Our results could be overstated if water consumption is also affected by the tax. Using alternative comparison groups, namely firms producing (a) fruit juice, (b) milk, (c) wine, or (d) perfumes, cosmetics and hygiene products, instead of bottled water firms, consistently produces comparable results (Table 10),

[11] As can be seen in Table 9 by comparing Panels A and B, the number of zeros in the sample is limited.

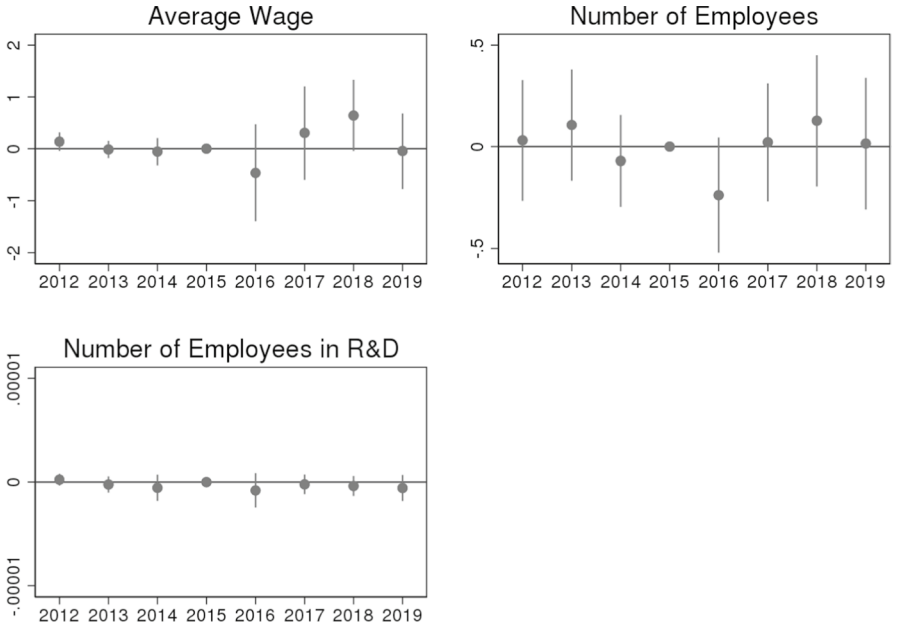

Fig. 4 Effects of the soda tax on workforce-related outcomes. Notes: Coefficients from Eq. (1) along with the 90% confidence intervals using standard errors clustered at the firm level. Scaling factors: average wage*10^{-2}, number of employees*10^{0}, number of employees in R&D*10^{-6}

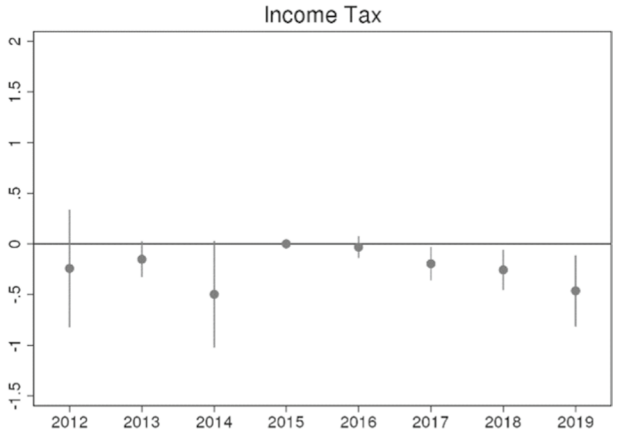

Fig. 5 Effects of the soda tax on corporate income tax payments. Notes: Coefficients from Eq. (1) along with the 90% confidence intervals using standard errors clustered at the firm level. Scaling factors: income tax*10^{0}

mitigating these concerns.[12] Lastly, results using the (continuous) treatment intensity variable, instead of the binary one, are highly similar, once again supporting the validity of our identification strategy (Table 11).

[12] Each group is considered separately. Event study graphs considering all groups provide very similar results to baseline and are available from the authors upon request.

6 Discussion and concluding remarks

This study contributes with evidence on the impacts of soda taxes for producers/importers and their workforce, and provides insights about total consumption effects (both in- and out-of-home)—two important gaps that were identified in the literature on the impacts of soda taxes. Using novel firm-level data on the near-totality of SSB firms in Portugal and relying on a comparator group of bottled water firms to identify causal effects, we find a significant 6.8% decrease in domestic sales. There is also some evidence of negative impacts of the soda tax on firms' financial health, namely a decrease in net income and an increase in liabilities. There is no evidence that employment in the soda manufacturing industry was affected. Any reformulation activity that may or may not have been induced by the introduction of the soda tax did not translate into higher numbers of employees working in R&D. The Portuguese soda tax seems to have been lucrative from a public finance standpoint, with virtually no impacts on forgone corporate income tax payments.

By looking at SSB producers/importers' domestic sales, this study complements the existing body of literature, which mostly considers retail sales (i.e., mainly in-home soda consumption). However, a distinction between the impacts of soda taxes on in-home and out-of-home consumption is not possible here; we only provide the aggregate picture at the firm level. Another limitation is that sales mix together a quantity effect and a price effect, which would also be important to separate to have a more complete discussion on incidence. There is evidence of about 100% pass-through of the Portuguese soda tax to final consumer prices, varying across groups of drinks with different sugar content/subject to a different tax rate, although it is unclear to which extent pass-through occurs at producer and/ or retailer levels (Gonçalves & Pereira dos Santos, 2020). We also find an impact of the tax on profits, so it is unlikely that the sales effect is solely a price effect. Furthermore, it is possible that we do not include the universe of SSB producers/importers because these firms are identified based on their main economic activity; in any case, any excluded firm is likely to be small. Finally, it is also unfortunate that we cannot link brands and drink portfolios to firms in our data, which would allow, for instance, looking into product innovation (which we do here indirectly by looking at employees in R&D) and considering potentially complex cross-product interdependencies on the supply-side (Agrawal & Hoyt, 2019), especially as products are subject to different tax rates on account of sugar content (Gillitzer et al., 2017; McCullough, 2018).

To conclude, governments still pondering the introduction or revision of their soda taxes should consider all economic agents; not just consumers and retailers, who have received most of the attention, but also producers/importers and workers. Our results inform about some of the impacts of soda taxes on the latter.

Appendix

See Table 3, 4, 5, 6, 7, 8, 9, 10 and 11.

Table 3 Balance tests

	P values	
	(1) Full sample	(2) Excluding largest firm
Domestic sales	0.090	0.398
Exported sales	0.034	0.080
Net income	0.225	0.690
Total income	0.081	0.352
Total expenses	0.080	0.347
Cash	0.164	0.332
Receivables	0.042	0.134
Liabilities	0.211	0.517
Average wage	0.415	0.507
Number of employees	0.178	0.987
Employees in R&D	0.359	0.267
Income tax	0.062	0.205

Table 4 Effects of the soda tax on domestic and exported sales: DiD estimates

	(1) Domestic sales	(2) Exported sales
SSB*Post	−0.125* (0.072)	−0.039 (0.035)
Adjusted R^2	0.100	0.068
$N \times T$	297	297
Retransformed marginal effects	−2,094,457* (1,199,742)	−394,6876 (3,522,233)

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: domestic sales*10^{-6}, exported sales*10^{-8}. Retransformed marginal effects, measured in euros, computed à la Norton (2022)

Table 5 Effects of the soda tax on net income, total income, and total expenses: DiD estimates

	(1) Net income	(2) Total income	(3) Total expenses
SSB*Post	−0.193 (0.205)	−0.007 (0.014)	−0.477 (0.335)
Adjusted R^2	0.093	0.075	0.062
$N \times T$	297	297	297
Retransformed marginal effects	−302,282 (320,858)	−675,932 (1,492,284)	−10,800,000 (7,874,021)

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: net income*10^{-6}, total income*10^{-8}, total expenses*10^{-2}. Retransformed marginal effects, measured in euros, computed à la Norton (2022)

Table 6 Effects of the soda tax on cash, receivables, liabilities, and corporate income tax payments: DiD estimates

	(1) Cash	(2) Receivables	(3) Liabilities	(4) Income Tax
SSB*Post	−0.240 (0.167)	0.047 (0.028)	0.444** (0.182)	−0.005 (0.123)
Adjusted R^2	0.078	0.162	0.030	0.042
$N \times T$	297	297	297	297
Retransformed marginal effects	−275,506 (193,449)	4,718,670* (2,815,845)	8,494,376** (3,584,575)	−4,683 (128,049)

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: cash*10^{-6}, receivables*10^{-8}, liabilities*10^{0}, income tax*10^{0}. Retransformed marginal effects, measured in euros, computed à la Norton (2022)

Table 7 Effects of the soda tax on labor-related outcomes: DiD estimates

	(1) Average Wage	(2) Number of Employees	(3) Number of Employees in R&D
SSB*Post	0.073 (0.43)	−0.046 (0.110)	−0.000 (0.000)
Adjusted R^2	0.011	0.048	0.095
N x T	297	297	107
Retransformed marginal effects	1017.1 (3354.2)	−3.8 (9.1)	0.0 (0.0)

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: average wage*10^{-2}, number of employees*10^{0}, number of employees in R&D*10^{-6}. Retransformed marginal effects, measured in euros or numbers of employees, computed à la Norton (2022)

Table 8 Effects of the soda tax on the main outcomes: Robustness

	(1) Net income	(2) Total income	(3) Total expenses	(4) Domestic sales	(5) Exported sales
A. 1% winsorization					
SSB*Post	−0.213 (0.190)	−0.006 (0.014)	−0.477 (0.335)	−0.130* (0.071)	−0.033 (0.029)
Adjusted R^2	0.096	0.073	0.062	0.101	0.060
$N \times T$	297	297	297	297	297
B. Excluding largest firm					
SSB*Post	−0.178 (0.222)	0.001 (0.014)	−0.524 (0.371)	−0.139* (0.072)	−0.004 (0.011)
Adjusted R^2	0.092	0.111	0.066	0.102	−0.001
$N \times T$	289	289	289	289	289
C. Excluding firms with < 90% turnover from main activity					
SSB*Post	−0.061 (0.213)	−0.000 (0.014)	−0.537 (0.373)	−0.137* (0.078)	−0.004 (0.011)
Adjusted R^2	0.056	0.113	0.070	(0.102	0.001
$N \times T$	265	265	265	265	265
D. Balanced panel					
SSB*Post	−0.137(0.255)	−0.005 (0.016)	−0.167* (0.089)	−0.180** (0.080)	−0.011 (0.011)
Adjusted R^2	0.113	0.143	0.041	0.150	0.010
$N \times T$	224	224	224	224	224
E. Excluding 2016					
SSB*Post	−0.307 (0.184)	−00.013 (0.016)	-0.417 (0.350)	−00.158** (0.077)	−00.048 (0.039)
Adjusted R^2	0.100	0.092	0.042	0.113	0.090
$N \times T$	260	260	260	260	260

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: net income*10^{-6}, total income*10^{-8}, total expenses*10^{-2}, domestic sales*10^{-6}, exported sales*10^{-8}

Table 9 Effects of the soda tax on the main outcomes: Robustness to alternative transformations

	(1) Net income	(2) Total income	(3) Total expenses	(4) Domestic sales	(5) Exported sales
A. ln(y)					
SSB*Post	−1.825*** (0.642)	−0.234 (0.363)	−0.161 (0.149)	−0.212** (0.099)	0.062 (0.519)
Adjusted R2	0.218	0.012	0.043	0.057	0.015
N x T	138	283	293	261	171
B. ln(y + 1)					
SSB*Post	−1.764***(0.620)	−0.673 (0.621)	−0.699 (0.489)	−0.335 (0.775)	−1.343 (0.987)
Adjusted R^2	0.151	−0.003	0.054	0.022	0.005
N x T	143	297	297	297	297

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: net income*10^{-6}, total income*10^{-8}, total expenses*10^{-2}, domestic sales*10^{-6}, exported sales*10^{-8}

Table 10 Effects of the soda tax on the main outcomes: Robustness

	(1) Net income	(2) Total income	(3) Total expenses	(4) Domestic sales	(5) Exported sales
A. Comparison group: fruit juices					
SSB*Post	−0.058 (0.189)	0.003 (0.013)	−0.439 (0.486)	−0.234*** (0.083)	−0.038 (0.035)
Adjusted R^2	0.098	0.016	0.006	0.150	0.070
N x T	198	198	198	198	198
B. Comparison group: milk					
SSB*Post	0.117 (0.176)	0.006 (0.013)	-0.503 (0.348)	-0.074* (0.044)	-0.039 (0.034)
Adjusted R^2	0.014	0.010	0.000	0.034	0.056
N x T	1668	1668	1668	1668	1668
C. Comparison group: wine					
SSB*Post	0.108 (0.175)	0.006 (0.013)	−0626* (0.330)	−0.080* (0.035)	−0.040 (0.034)
Adjusted R^2	0.027	0.034	0.014	0.083	0.050
$N \times T$	5834	5834	5834	5834	5834
D. Comparison group: perfumes, cosmetics, and hygiene products					
SSB*Post	0.104 (0.175)	0.004 (0.013)	−0.478 (0.368)	−0.115** (0.052)	−0.042 (0.035)
Adjusted R^2	0.032	0.032	0.004	0.086	0.071
$N \times T$	689	689	689	689	689

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: net income*10^{-6}, total income*10^{-8}, total expenses*10^{-2}, domestic sales*10^{-6}, exported sales*10^{-8}

Table 11 Effect of the soda tax on the main outcomes: DiD with treatment intensity

	(1) Net income	(2) Total income	(3) Total expenses	(4) Domestic sales	(5) Exported sales
SSB_int*Post	−0.161 (0.192)	−0.014 (0.013)	−0.611 (0.383)	−0.141* (0.073)	0.040 (0.031)
Adjusted R2	0.090	0.084	0.072	0.102	0.062
$N \times T$	297	297	297	297	297

Standard errors in parentheses clustered at the firm level. *p < 0.1, **p < 0.05, ***p < 0.01. Scaling factors: net income*10^{-6}, total income*10^{-8}, total expenses*10^{-2} , domestic sales*10^{-6}, exported sales*10^{-8}

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Declarations

Conflict of interest The authors declare no competing interests.

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