The impact of the French soda tax on prices and purchases: An ex post evaluation

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Abstract

We estimate the price and consumption effects of the 2012 French tax on sweetened non-alcoholic drinks using a Difference-in-Difference approach. Our identification strategy rests on alternative counterfactual specifications: (1) using Italian data as a natural control group; (2) using data on mineral and spring water prices and purchases as the placebo good. We use French and Italian consumer price indices, purchase prices and quantities from the 2011 and 2012 EuroPanel home-scan surveys for two French regions and two neighbouring Italian regions, and expenditure data from the 2011 and 2012 Italian Expenditure Survey. Our results suggest that the tax is transmitted to the prices of taxed drinks, with full transmission for soft drinks and partial transmission for fruit juices. The tax effects on purchased quantities are small (-2% for soft drinks), but they are larger when households in the top consumption quartile are considered (-10%).

JEL classification: I18, D12

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1 Introduction

Taxation of sweetened beverages (SBs) as a mean to reduce the risk of excess weight and non-communicable diseases, especially in children, has been a key component of nutrition policies for many governments over the last decade. However, the ex-post empirical evidence on the effectiveness of these taxes is still limited. In this study, we evaluate the impact of a tax on sweetened non-alcoholic drinks introduced in France in January 2012, and we provide quasi-experimental evidence on its effect on prices and purchased quantities.

Taxation of soft drinks dates back to 1933, when California introduced a 7% sales tax. By 2014, 34 US states had introduced a soda tax[1], and between 2014 and 2016 the introduction of a city-level tax was approved in seven US cities, five of them following popular ballots (Paarlberg et al., 2017). However, the main outcomes of these taxes has been the generation of revenues rather than actual changes on behaviors. This has been explained with the relatively low level of the taxes, all below 10% as opposed to the 20% level indicated by experts as the minimum to generate significant changes in weight and health outcomes (Briggs et al., 2013; Mytton et al., 2012; Fletcher et al., 2010). Outside the US, according to the Nourishing data-base[2], at least 15 national governments have enacted soda taxes over the recent years, including an 18% tax on sugary drinks introduced in Chile in 2015 (Guerrero-López et al., 2017) and a $ 0.07 per liter tax in Mexico (Colchero et al., 2017). In Europe, taxes on soft drinks are currently implemented in the UK (from April 2018 sugared drinks are taxed up to £0.24 per liter depending on their sugar content), Belgium (from 2016, €0.068 per liter), Hungary (from 2011, $ 0.24 per liter), Norway (from 1981, $ 0.40 per liter) and Finland, where an excise duty tax exists since 1940 and currently amounts €0.22 per liter for soft drinks exceeding 0.5% sugar content, €0.11 per liter otherwise. The French soda tax was introduced in January 2012 and set to €0.0716 per litre. It applies to all sweetened drinks, including sugar substitutes used in diet drinks, and is paid by manufacturers, processors and importers.

Despite the growing spread of this type of fiscal measures across the world, there are conflicting visions about their effectiveness in reducing consumption of sugary drinks. The evidence base is still incomplete, and the findings inconsistent, not least because studies are heterogeneous in terms of design, tax levels and aims. Until recently, most of the quantitative evidence has been based on demand simulations. These simulations necessarily rely on key empirical assumptions on the pass-through from producer prices to retail prices, and rest on

[1] Chriqui JF, Eidson SS, Chaloupka FJ. State Sales Taxes on Regular Soda (as of January 1, 2014) - BTG Fact Sheet. Chicago, IL: Bridging the Gap Program, Health Policy Center, Institute for Health Research and Policy, University of Illinois at Chicago; 201 `www.bridgingthegapresearch.org`

[2] World Cancer Research Fund, `http://www.wcrf.org/int/policy/nourishing-framework`

elasticities and behavioural parameters whose estimates depend heavily on the demand model specification (Cornelsen et al., 2016) and the variability in price data relative to the tax level. Based on the existing evidence, a report published by the World Health Organization in 2016 suggests that these targeted taxes should raise the price of targeted drinks of at least 20% to generate meaningful impacts in terms of calorie intakes, weight and risk of non-communicable disease[3].

The rising adoption of soda taxes in recent years, as well as the increasing availability of purchase data, should allow a more accurate ex post assessment of their effects, at least in the short-term. Recent ex-post evaluations are suggestive of soda taxes generating significant reduction in purchased quantities. Colchero et al. (2017) exploit panel data on food and drink purchases of 6,645 Mexican households to estimate an average reduction of 7.6% in purchased volumes of taxed beverages in Mexico over the first two years of the tax implementation. The 2014 Mexican tax amounted to 1 peso per litre (about 0.08 USD at that time), and a previous study (Colchero et al., 2015) had shown a full pass-through to consumer prices.

The ex-post evidence gathered from the city-level Berkeley soda tax is particularly interesting for two reasons. First, the level of the tax ($ 0.34 per litre) is much higher than most of the fiscal measures adopted elsewhere. Second, the tax was adopted in November 2014 as a ballot measure, and the debate prior to the vote is likely to have generated information effects on consumption beyond the mere price effect. Two studies (Falbe et al., 2016; Silver et al., 2017) have evaluated the impact of the tax exploiting neighbouring areas as control groups. As for the other ex-post studies, there was robust evidence of a pass-through to retail prices. The estimates also show a large reduction in purchased quantities of taxed drinks over the first year of implementation, estimated at -9.6% by Silver et al. (2017) and at 21% by Falbe et al. (2016), although both studies also register an increase in purchases in the neighbouring (control) areas, 6.9% and 4%, respectively.

To the best our knowledge, the only ex post evaluation on the French soda tax is the one by Berardi et al. (2016) that focuses on the effect of the excise tax on retail prices, and there are no studies looking at the ultimate impact on purchases or consumption. Based on a large dataset on retail prices, Berardi et al. (2016) consider a sub-set of non-taxed goods with pre-tax price patterns similar to the taxed categories as a natural control group. Their soda category, which includes regular and diet sodas, exhibits an average pass-through around 7 euro-cents per liter over the first 6 months of the tax. Fruit drinks and flavored waters show a slightly smaller pass-through. These empirical findings are

[3]WHO, Fiscal Policies for Diet and Prevention of Noncommunicable Diseases: technical meeting report, 5-6 May 2015, Geneva, Switzerland, `http://apps.who.int/iris/bitstream/10665/250131/1/9789241511247-eng.pdf?ua=1`

consistent with a simulation-based study by Bonnet and Réquillart (2013) based on pre-tax data, that predicted that French firms would be likely to transmit, and even over-transmit, cost changes or excise taxes to consumers.
In this study, we evaluate the impact of the French soda tax on retail prices and purchased quantities. We also explore whether the tax has had differential effects on households with a heavier consumption of taxed drinks. Our evaluation is based on panel household purchase data collected through home-scan devices in four regions in the twelve months preceding and following the introduction of the tax. We consider two French regions (Rhone Alpes and Provence-Alpes-Cote d'Azure) where households are exposed to the tax, and two neighboring Italian regions (Piemonte-Val D'Aosta and Liguria) that act as a natural control group. Because of potential structural differences among these regions, we adopt a Difference-in-Difference panel regression to control for selection on non-observable variables, allowing for fixed cross-section effects and country-specific linear time trends. We check for the robustness of our results by adopting different specifications of the Difference-in-Difference model, and by considering alternative sources of data, such as the official Consumer Price Indices at national level, and household purchases for the Italian household expenditure survey as an alternative to the home-scan data-set.
The paper is structured as follows. The key elements of the French soda tax are summarized in Section 2, the commercial panel data and other data sources are described in Section 3, and the evaluation methods are presented in Section 4. Section 5 reports the main results of our evaluation, and some conclusions are drawn in Section 6.

2 Policy background

The French tax on sweetened soft drinks was incorporated in the 2012 French budget bill (Law No.2011-1977) and entered into force on January 2012. It applies to all non-alcoholic beverages containing added sugar (e.g. sodas, fruit juice) or sweeteners (e.g. diet drinks) and amounts to 7.16 eurocents per litre excluding VAT, or 7.55 eurocents per litre at the retail level where a 5.5% VAT is applied. The tax is paid by manufacturers and processors in France and by French importers.
In its initial proposal[4], the tax was lower (3.58 cents per liter), it did not apply to artificially sweetened drinks and it was framed within the broader scope of the French National Nutrition and Health Program (NNHP) among public measures targeting eating patterns to promote healthier lifestyles. The explicitly stated rationale of the tax was originally to discourage the consumption of sugary and sweetened beverages and direct consumers towards other beverages.

[4]Projet de loi de finances pour 2012, 28 September 2011.

The proposal caused a strong opposition by the French Food Industry Association and by those producers holding the largest shares in the non-alcoholic beverage market[5]. The reference to the NNHP and to healthy eating objectives does not appear in the final text of the law, approved on December 2011, where the tax level is doubled relative to the original proposal.

3 Data

Our analysis is based on three different data sources: (a) commercial home-scan data from EuroPanel; (b) official consumer price indices at the national level; (c) household purchases from the Italian household expenditure survey. The home-scan data-set provides household level information on purchases for home consumption and on purchase prices. Estimates on the effect of the tax on prices are also based on official consumer price index, which are available at the national level for both countries, but with a higher level of aggregation. Finally, since the available home-scan panel for the two Italian regions is relatively small and less precise than the French counterpart, we check for the robustness of our impact estimates on purchases by using data from Italian household expenditure survey.

3.1 Home-scan data and household purchases

We use commercial home-scan data provided by EuroPanel from a random sample of French and Italian households living in four neighbouring regions: Rhone Alpes and Provence-Alpes-Cote d'Azure in France and Piemonte-Val D'Aosta and Liguria in Italy[6].

The harmonized dataset consists of 2,928 French households and 400 Italian households observed over the period between 1 January 2011 and 31 December 2012, conditional on at least one purchase of non-alcoholic beverages in each of the two years. Weekly expenditures and purchased quantities are available for the following drink categories: regular soft-drinks; diet soft-drinks; non-pure fruit juices; mineral water; pure fruit juices. All drinks included in the first three categories are subject to the tax. The regular soft drink category includes flavoured mineral waters, also taxed, whereas the mineral water category only includes non-taxed products. Pure fruit juices with no added sugars are also exempt from the tax.

[5]USDA Foreign Agricultural Service, 2011, France to tax soft drinks - U.S. Companies to pay the most, GAIN Report, `https://gain.fas.usda.gov/Recent%20GAIN%20Publications/France%20to%20tax%20soft%20drinks.%20U.S.%20Companies%20to%20pay%20the%20most._Paris_France_10-26-2011.pdf`

[6]EuroPanel is a joint venture between Kantar Worldpanel and GfK. Specifically, Kantar WorldPanel France has provided the data on the French sub-sample and GfK Italy has provided the data on the Italian sub-sample

Information on prices can be derived from our home-scan dataset, as the ratios between expenditures and purchased quantities represent the unit prices paid by the household for each drink group.
In addition, the harmonized dataset includes a set of household characteristics: household size, presence of children aged under 15, age of the person responsible for food purchases and a binary variable for job status (employed or unemployed). Harmonization of information on household incomes is not possible as income information was not collected in the Italian survey. As explained in the Appendix, we adopt a classification rule to achieve some comparability in terms of socio-economic status and explore the role of inequalities.
Table 1 below shows the difference in the two samples as reflected by the available demographics. The French sample has a larger proportion of households with children aged less than 15, and a higher proportion of those responsible for the food shopping are employed. The percentage of households with a medium-high and high socio-economic status is higher in the two Italian regions relative to their French counterparts. Since the classification of socio-economic status is relative (country-specific), this comparison suggests that the two Italian regions are wealthier than the French ones relative to the respective national benchmark. The two samples also differ in terms of age distribution, as the Italian sample has a lower proportion of young households and a higher proportion of households where the person responsible for food shopping is over 55.

3.2 Prices

The first condition for a tax to influence consumption is obviously that it is transmitted to consumers. We exploit official consumer price indices and home-scan data from EuroPanel to test whether the policy has actually changed the costs borne by the households to purchase unhealthy drinks. In principle, producers and/or retailers might fully or partially absorb the excise tax, leading to incomplete transmission.

3.2.1 Consumer Price Indices

We use monthly national Consumer Price Indices (CPIs) from 2007 to 2016 as released by INSEE for France[7] and ISTAT for Italy to investigate the extent of the pass-through of the tax to retail prices. National CPIs from both countries are available for the following drink categories[8]: soft drinks (including both sweetened and diet beverages); mineral and spring waters; fruit and vegetable juices. In order to account for the potential effects of differential inflation rates (which in 2012 was +3% in Italy and +1.3% in Metropolitan France), these

[7]The indices refer to Metropolitan France only, i.e. they exclude Overseas France
[8]5-digits level COICOP classification represents the highest level of product detail for CPIs

Table 1. Descriptive statistics: household demographics, by country.

	French Regions	Italian Regions	T-test
Presence of children <15 y.o.	0.333	0.230	-0.103***
	(0.471)	(0.421)	(0.025)
RP employed[a]	0.714	0.412	-0.302***
	(0.452)	(0.493)	(0.024)
Low SES[b]	0.287	0.183	-0.104***
	(0.452)	(0.386)	(0.024)
Medium-low SES	0.124	0.212	0.089***
	(0.330)	(0.409)	(0.018)
Middle SES	0.416	0.297	-0.118***
	(0.493)	(0.457)	(0.026)
Medium-high SES	0.086	0.193	0.106***
	(0.281)	(0.395)	(0.016)
High SES	0.087	0.115	0.028*
	(0.281)	(0.319)	(0.015)
RP <35 years old	0.221	0.080	-0.141***
	(0.415)	(0.271)	(0.021)
RP 35-44 years old	0.248	0.223	-0.03
	(0.432)	(0.416)	(0.023)
RP 45-54 years old	0.184	0.215	0.03
	(0.388)	(0.411)	(0.021)
RP 55-64 years old	0.163	0.210	0.047**
	(0.370)	(0.408)	(0.020)
RP >64 years old	0.183	0.273	0.090***
	(0.386)	(0.446)	(0.021)
Household size (average)	2.516	2.547	0.031
	(1.143)	(1.053)	(0.060)
Observations			
Number of obs.	2928	400	
Liguria	-	82	
Piemonte-Val D'Aosta	-	318	
Provence-Alpes-Cote d'Azur	1225	-	
Rhone Alpes	1703	-	

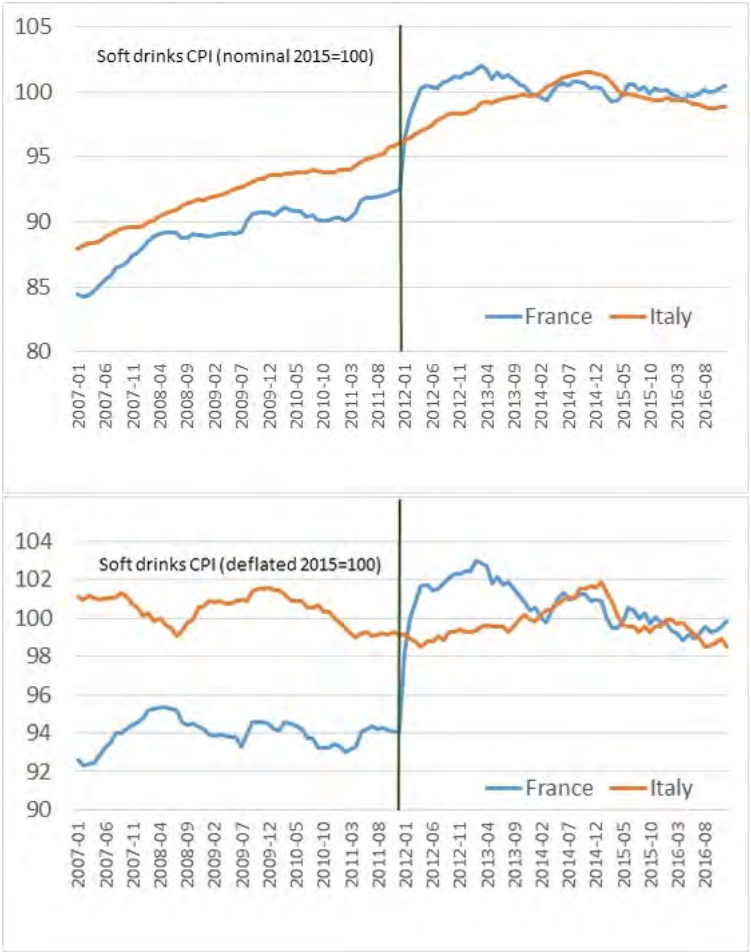
Notes: Numbers in brackets are Standard Deviations for proportions and Standard Errors of t-tests for the difference. * p<0.1; ** p<0.05; *** p<0.01.

[a] Household Reference Person

[b] Socio-Economic Status (SES) is classified as: bottom 15%(low); 15th-35th percentile (medium-low); 35th-65th percentile (middle); 65th-85th percentile (medium-high); top 15% (high). See the Appendix for details.

indices were deflated by an all-item consumer price from the same sources. Figure 1 displays nominal and deflated CPIs patterns from 2007 to 2016. The graph is suggestive of a meaningful real price increase of soft drinks in France in the first two years of the tax implementation, while it shows a substantial overlap of French and Italian price patterns from 2014.

Figure 1: **Nominal and real soft drink consumer price indices in France and Italy, 2007-2016 (2015=100)**



3.2.2 Price levels from home-scan data

The ratio between expenditures and purchased quantities as obtained from the home-scan data-set determines the purchase unit values, that are a combination of the retail price levels and consumer choices in terms of quality and basket composition. There is a consolidated literature on the difference between unit values and prices (Deaton, 1988; Crawford et al., 2003), where the elicitation

of retail prices rests on the assumption that households living in the same geographical area in a given time period face the same price, and any heterogeneity observed at that level stems from different household choices rather than different prices. Thus, a simple but effective way to obtain indirect estimate of retail prices consists in computing the weekly averages of unit values across households living in the same region.

Table 2 shows the averages of the monthly CPI (2015=100) and of the weekly purchase prices in Euros for France and Italy, in 2011 and 2012. The CPIs are at the national level and purchase prices refer to the regions within each country available in our home-scan data-set. All figures are in real terms as the price series were deflated by the all-item consumer price index of the respective country. The table also reports the percent change between 2011 and 2012 as estimated by a basic pre-post model on the natural logarithms of the price series.

The data provides consistent evidence of an increase in all prices but those of water in France, whereas all Italian prices where stable or decreasing, with the exception of regular soft drinks. The rough difference in soft drink prices in France as captured by the real CPIs is around 7.7%. Considering purchase prices from home-scan data, the average price of soft drinks went up by about 6 eurocents, or 5.7%. The estimated price increase is similar for regular soft drinks and diet soft drinks, and smaller for fruit juices (3 eurocents or +2.5%), again with a negligible difference between non-pure juices (taxed) and pure fruit juices (not taxed). Considering the Italian price data, the analysis of CPIs suggests stable prices, and a small reduction for water (-1.8%). Soft drinks purchase prices for the Italian regions are very similar to the French ones in 2011, but the average increase in 2012 is smaller and non-significant (2 eurocents, or +1.2%). However, this average change is the outcome of a significant increase in the price of regular soft drinks (+3.9%) and a relatively large decline in the real price of diet soft drinks (-15%), although these estimates may also depend on the smaller sample size and larger variability in the Italian home-scan data, as reflected by the larger standard errors. Interestingly, real prices of mineral and spring water are stable in both country, with an average price which is substantially larger in France (0.41 vs. 0.26 euros per litre).

3.3 Purchased quantities

Table 3 shows average drink purchases in 2011 and 2012 in the Italian and French sub-samples as estimated from the home-scan data-set. On average, total beverage purchases in the Italian regions are twice as large as those in French regions, mainly because of mineral water consumption, which is particularly large in Italy (around 3.3 liters per-capita per week in 2011 compared to 1.1 liters per capita in the French regions). With regard to taxed beverages, the largest difference is observed for regular soft drinks. On average, consumers in the

Table 2. Average prices and pre-post differences.

	France			Italy		
	2011	**2012**	**(1)**	**2011**	**2012**	**(1)**
			Real CPI (2015=100)			
Soft drinks	93.84	101.36	0.077***	99.23	98.99	-0.002**
	(0.50)	(1.20)	(0.002)	(0.21)	(0.28)	(0.001)
Fruit Juices	101.03	104.70	0.036***	101.77	101.59	-0.002
	(2.10)	(0.54)	(0.004)	(0.43)	(0.28)	(0.001)
Water	108.61	107.47	-0.011***	103.27	101.42	-0.018***
	(0.67)	(1.08)	(0.003)	(0.57)	(0.48)	(0.001)
	Real purchase prices from home-scan data (€/liter)					
Soft drinks	1.08	1.14	0.056***	1.10	1.12	0.012
	(0.06)	(0.06)	(0.007)	(0.18)	(0.18)	(0.022)
Regular soft drinks	1.12	1.18	0.057***	1.13	1.17	0.039**
	(0.07)	(0.08)	(0.008)	(0.17)	(0.16)	(0.018)
Diet soft drinks	0.95	1.02	0.067***	0.94	0.83	-0.150**
	(0.05)	(0.06)	(0.007)	(0.43)	(0.37)	(0.070)
Fruit Juices	1.46	1.49	0.025***	1.51	1.38	-0.075***
	(0.04)	(0.04)	(0.004)	(0.40)	(0.25)	(0.028)
Non-pure fruit juices	1.62	1.65	0.018***	1.41	1.38	-0.026
	(0.05)	(0.04)	(0.004)	(0.38)	(0.35)	(0.034)
Pure fruit juices	1.31	1.33	0.021***	1.56	1.36	-0.118***
	(0.06)	(0.07)	(0.006)	(0.50)	(0.30)	(0.034)
Water	0.41	0.41	-0.002	0.26	0.26	-0.014
	(0.02)	(0.02)	(0.006)	(0.04)	(0.04)	(0.019)

(1) Pre-post model in logs of real prices. CPIs monthly national series are from INSEE and ISTAT for France and Italy, respectively. home-scan purchase prices are deflated by national overall CPIs. * p<0.1; ** p<0.05; *** p<0.01.

Table 3. Average purchased quantities by country and year (weekly per capita litres).

	French regions		Italian regions	
	2011	2012	2011	2012
Taxed drinks	0.615	0.605	0.853	0.741
	(0.77)	(0.76)	(0.65)	(0.65)
Regular soft drinks	0.337	0.326	0.62	0.537
	(0.58)	(0.54)	(0.55)	(0.52)
Diet soft drinks	0.111	0.114	0.085	0.064
	(0.36)	(0.38)	(0.20)	(0.16)
Non-pure juice	0.167	0.164	0.148	0.14
	(0.25)	(0.28)	(0.17)	(0.22)
Non-taxed drinks	1.278	1.349	3.325	3.403
	(1.69)	(1.82)	(2.58)	(2.79)
Pure juice	0.175	0.189	0.036	0.026
	(0.27)	(0.29)	(0.08)	(0.07)
Water	1.102	1.159	3.289	3.377
	(1.64)	(1.76)	(2.57)	(2.77)
Total drinks	1.896	1.957	4.209	4.169
	(1.99)	(2.11)	(2.85)	(3.06)
N	2958	2958	400	400

Notes: Standard Deviations in brackets

French regions purchased about one can per week in 2011, whereas the Italian region counterparts purchased almost two cans per week. However, purchases of diet sodas and non-pure juice were slightly lower in the Italian regions.
A pre-post comparison of national averages shows a reduction of around 10 ml in per capita weekly purchases of taxed drinks after the introduction of the tax in French regions. The reduction observed in Italy, however, is even greater, with no tax enforced. While these figures are suggestive of a lack of impact, the question is whether a rough double difference computation is able to capture the potential effects of the tax, since it does not account for the panel structure of the data, hence any heterogeneity across households (e.g. heavy consumers vs. occasional purchasers) and over time (e.g. differential trends, seasonal effects).

3.3.1 Consumption data from the Italian household expenditure surveys

The available sample for the two Italian regions from EuroPanel provides longitudinal information on 400 households that have purchased at least one non-alcoholic drink in each of the two year. Since this sample is much smaller than its French counterpart, hence affected by a larger sampling error, we extract data

Table 4. Consumption indices by regions and year (Italian HBS, first 2011 quarter = 1).

	French regions		Italian regions	
	2011	2012	2011	2012
Soft drinks	1.055	1.013	1.022	1.006
	(2.051)	(2.137)	(1.720)	(1.672)
Fruit Juices	0.963	0.972	1.011	1.062
	(1.966)	(2.297)	(1.130)	(1.257)
Water	0.984	1.010	1.010	0.929
	(1.279)	(1.275)	(1.519)	(1.627)
N	10519	10770	2331	2339

Notes: Standard Deviations in brackets

from the 2011 and 2012 Italian household expenditure surveys (HES) for the same regions, with the purpose of running robustness checks. The Italian HES runs on a yearly basis and collects information on purchase expenditures from about 23,000 Italian households. Relative to the home-scan data, this data-set has several shortcomings: (1) there is no longitudinal dimension as a new sample is extracted every year; (2) expenditures for each household are recorded through a two-weeks diary, which increases the proportion of zero expenditures; (3) there is no information on purchased quantities, only monetary values of expenditures; and (4) there is a lower level of detail (i.e. purchase data refer to soft drinks, fruit juices and water). However, the number of household purchasing non-alcoholic drinks in the relevant Italian regions (Liguria, Piedmont and Val D'Aosta) is relatively large (2,331 households in 2011, 2,339 in 2012) compared to the 400 households available in the home-scan panel data-set.

Given that data on purchased quantities are not provided, we use real expenditures as a proxy. A real expenditure index (REI) is obtained by dividing the nominal purchase expenditure of each household by the appropriate regional monthly consumer price index. In order to make the REI comparable with purchased quantities from the French home-scan data-set, we normalize both the Italian REIs and the French quantities by dividing them by the respective average values from the first quarter of 2011.

Table 4 replicates the comparison between France and Italy using consumption indices from the home-scan data-set for France and data from the Italian HES for Italy.

4 Methodology

4.1 Difference-in-difference model

In order to estimate the impact of the soda tax on beverage prices and purchases we consider the two neighbouring Italian regions as a reasonable control group for the French regions under analysis and resort to a Difference-in-Difference (DID) framework. Similarly, the DID framework can be applied to national consumer price indices for France and Italy. Our identification strategy rests on the assumption that any border effect could be ignored. This assumption is reasonably safe even when we consider regional data, given the dimensions of the four regions, as only a very small number of households in our sample is located at a distance which makes the cross-border trip convenient[9]. Thus, we exploit the panel structure of the data and estimate a set of DID models which allow for fixed cross-sectional effects and differential time trends. The specification of the general model is the following:

$$Y_{ht} = \gamma_h + \lambda_0 \cdot trend + \lambda_1 \cdot F_{ht} trend + \zeta_{hs} + \delta T_{ht} + \eta_{ht} \tag{1}$$

where Y_{ht} is the outcome observed on cross-sectional unit h at time t; γ_h are cross-sectional fixed effects; $\lambda_0 \cdot trend + \lambda_1 \cdot F_{ht} trend$ are linear time trends, allowing for a different slope between French observations ($F_{ht} = 1$) and Italian observations ($F_{ht} = 0$); ζ_{hs} is a set of seasonal effects; T_{ht} is the DID interaction term, which assumes a value of 1 for French observations in 2012, and 0 otherwise and η_{ht} is a randomly distributed error term. Under the DID approach, the coefficient δ yields the average effect of the tax on exposed observations.
To explore the average effect of the tax on prices we estimate equation (1) on national Consumer Price Indices as provided by the National Statistical Offices and on regional average prices as computed using home-scan data. To explore the average effect of the tax on purchases we estimate Equation (1) on household-level purchased quantities using home-scan data for the four regions. According to the outcome variable explored, cross-sectional fixed effects have different specifications which depend on the unit of analysis h (i.e. country, region or household).

4.2 Outcome variables

National Consumer Price Indices. A first estimate of the pass-through of the tax to consumer prices is based on official national CPIs. The DID model in

[9]For example, someone living in Nice should drive about 25 miles to cross the border, and pay about €2.50, which correspond to the total amount of the tax for the purchase of about 33 litres of taxed drinks

Equation (1) is estimated using French and Italian monthly time series, and the specification of the fixed cross-sectional effects reduces to two national intercepts. The model is estimated for each of the three drink categories for which data are available, i.e. soft drinks (regular & diet), fruit juices (pure and non-pure), and water. The price indices are taken in natural logarithms, so that the estimated treatment effect can be interpreted as a percent change.

Regional average prices. In order to explore the pass-through of the tax at the higher level of item disaggregation provided by the home-scan data, the DID Equation (1) is estimated on weekly average regional prices computed on home-scan data. For each of the four regions, the price of each drink category is computed as the average of the unit values paid by each household for those drinks in a given week. While averaging unit values does not rule out that some of the price variation across regions and weeks might also depend on aggregation and quality choices, allowing for fixed regional effects and quarterly time effects controls for these potential sources of heterogeneity. Hence, in our DID price model, the resulting dataset consists of a panel of four cross-sectional units (the regions) and 104 time periods (one for each week over the two years of our data), and the model specification includes four regional fixed effects. As for price indices, the outcome variable enters equation (1) in natural logarithms.

Household average purchases. Equation (1) is estimated on a household-level panel dataset where purchased quantities are aggregated for each household over a period of 13 weeks (one quarter). The aggregation over a quarter mitigates the potential "zero bias" associated with stockpiling and heterogeneity in purchase frequencies, but we refer to the average weekly per capita purchase as a measurement unit, for ease of interpretation. In this case, the estimation dataset is a balanced panel that includes all households in each of the eight quarters of 2011 and 2012, including zeroes when the household has not purchased the product in that quarter. The model specification includes household-specific fixed effects. We take the natural logarithms of the purchased quantities, and we adopt an inverse hyperbolic sine transformation for zero purchases (Burbidge et al., 1988).

Purchases by heavy consumers. Considering the possibility of heterogeneous effects of the tax, we estimate equation (1) on the sub-sample of heavy consumers, defined as those in the top 25% in terms of their annual household purchases of taxed drinks (regular and diet soft drinks and non-pure fruit juice) in the year 2011, before the tax was introduced. The top 25% corresponds to an average yearly purchase of 103.3 litres and 130.4 litres of taxed drinks in France and Italy, respectively.

4.3 Alternative models and robustness checks

The key identification assumption behind equation (1) is that any selection bias implied by using data from Italy to build the counterfactual and not captured by the fixed effects is either constant over time, or - if it evolves over time - this evolution is linear. The relatively short time span covered by our home-scan data and the smaller size of the Italian data-set make it difficult to provide stringent tests of this assumption. Thus, in order to validate estimates from the reference model, we proceed with a variety of tests based on different specifications and data.

4.3.1 Difference-in-difference using water as the placebo good

A first alternative specification is based on a different identification assumption for the policy effect, which does not require the use of the Italian data. More specifically, mineral and spring water can be used as a "placebo" good under the assumption that the tax does not affect the price and purchases of mineral and spring water in France. Taken in its stricter interpretation, this assumption rules out substitution between taxed drinks and water. Under a more relaxed view, even in presence of cross-price responses and substitutions, one might refer to a different outcome definition, i.e. the price of drinks relative to water prices and the ratio of drinks purchases relative to water purchases. The fact that average water prices and purchases have been stable between 2011 and 2012 (see Tables 2 and 3) suggests that the assumption between this identification strategy is not unreasonable. Operationally, we proceed by defining our outcome measures as $Z_{ht} = Y_{ht}^G - Y_{ht}^W$ where Y_{ht}^G is the natural logarithm of the selected outcome for the G-th drink and Y_{ht}^W is the corresponding (log) outcome for water. Under this specification, the difference-in-difference specification, assuming parallel trends between the outcome on the selected drink and water, is the following:

$$Z_{ht} = \gamma_h + \zeta_{hs} + \delta P_{ht} + \eta_{ht} \tag{2}$$

where γ_h are cross-sectional fixed effects; ζ_{hs} is a set of seasonal effects; P_{ht} is a binary variable equal to 1 for observations referring to the year 2012 when the tax is in place, and 0 otherwise; and η_{ht} is a randomly distributed error term. The coefficient δ corresponds to the Difference-in-Difference interaction term and yields the average effect of the tax on exposed observations.

4.3.2 Data from the Italian household expenditure survey

A second robustness check refers to the reliability of the data from the Italian EuroPanel homescan data-set. As an alternative source of information, we exploit data for the selected regions from the Italian HES, as described in Section 3.3. We estimate equation (1) on the full sample, and on the subsect of

heavy consumers. Since the French EuroPanel home-scan data follow a panel structure, while the Italian counterpart consists in cross-sectional surveys run on a yearly basis, we maintain the quarterly aggregation of purchases for French households, and we treat household observations from different quarters as independent observations. The sub-sample of heavy consumers is defined by the top 25% households in terms of their 2011 consumption of soft drinks, based on the indices described in Section 4.2.

4.3.3 Differential fixed time effects

A further alternative model specification consists in a basic fixed time effect model, where the quarterly time effects are allowed to be different between the treated and counterfactual groups over the whole time span. Since no explicit formulation of the time period when the policy is implemented enters the model, this specification allows to follow the evolution in the outcome difference between the two countries. A graphical inspection of the estimates of the differential time effect may be useful to identify: (a) whether the policy implementation is associated with a shift in the differential time effect; (b) potential time patterns in the effects of the policy. Thus, we estimate the following model:

$$Y_{ht} = \gamma_h + \lambda_{0t} + \lambda_{1t} F_{ht} + \eta_{ht} \tag{3}$$

where Y_{ht} is the outcome observed on cross-sectional unit h at time t; γ_h are cross-sectional fixed effects; $\lambda_{0t} + \lambda_{1t} F_{ht}$ are time fixed effects, differently specified for French observations ($F_{ht} = 1$) and Italian observations ($F_{ht} = 0$); and η_{ht} is a randomly distributed error term. An analysis of the time patterns in λ_{1t} may provide insights on policy effects and their evolution over time.
Similarly, one may look at the differential effect within the model based on French data only, using water as the counterfactual. The specification becomes:

$$Z_{ht} = \gamma_h + \delta_t + \eta_{ht} \tag{4}$$

where Z_{ht} is the same log-difference outcome variable as in equation (2), and δ_t are fixed time effects which capture the evolution of the outcome variable relative to water as the counterfactual good.

5 Results

5.1 Impact on prices

Table 5 shows estimates of the tax effects on national and regional consumer prices. Estimates are provided for equations (1) and (2), and for the two data-sources, national Consumer Price Indices and weekly regional prices obtained

Table 5. Tax impact on real prices.

	Monthly CPIs				Weekly regional prices	
	2007-16	2007-16	2011-12	2011-12	2011-12	2011-12
	(a)	**(b)**	**(a)**	**(b)**	**(a)**	**(b)**
Soft drinks	0.082***	0.090***	0.056***	0.088***	0.047*	0.057***
	(0.003)	(0.006)	(0.005)	(0.005)	(0.018)	(0.008)
Regular soft drinks	-	-	-	-	0.049*	0.059***
					(0.019)	(0.009)
Diet soft drinks	-	-	-	-	0.139	0.068***
					(0.068)	(0.009)
Fruit Juices	0.042***	0.050***	-0.002	0.046***	-0.013	0.026***
	(0.006)	(0.004)	(0.009)	(0.002)	(0.044)	(0.007)
Non-pure fruit juices	-	-	-	-	0.006	0.019***
					(0.031)	(0.007)
Pure fruit juices	-	-	-	-	-0.000	0.023**
					(0.019)	(0.009)
Water	-0.006	-	0.001	-	-0.009	-
	(0.006)		(0.007)		(0.013)	
N	240	120	48	24	208	104

(a) Diff-in-diff with Italy as the control, differential trends, seasonality, see equation (1).
(b) Diff-in-diff with water as the control, common trend, seasonality, see equation (2)
Prices are real (deflated by the overall CPI) and in logs. * p<0.1; ** p<0.05; *** p<0.01.

from the EuroPanel home-scan data-set. All estimates are consistent with a significant increase in the real price of soft drinks. The estimated tax effects are sistematically higher when equation (2) is used, i.e. when using French data only, and water as the counterfactual price. Estimated impacts are also higher when estimated on CPIs at the national level, and using the longer sample (2007-2016). The estimated impact considering only one year before and after the policy, soft drinks as an aggregate, and Italian prices as the conterfactual observations for the difference-in-difference ranges between +4.7% (regional prices) and +5.6%. When water is the counterfactual good, these estimates rise to +5.7% and +8.8%, respectively, and the treatment effect based on the 2007-16 CPI sample is the highest, with real price increases by +8.2% and +9%, respectively.

Considering that the average 2011 price for soft drinks in France was 1.08 €/litre [10] , a 5% real increase corresponds to about 5.4 eurocents per litre, and a 9% increase to 9.7 eurocents/litre. This, compared to the (nominal) excise tax of 7.55 eurocents per litre, shows that the tax transmission to soft drink prices is likely to have been complete, in the most conservative scenario at least 70% of the tax has been transmitted to retail prices, and our estimates are even suggestive of a potential over transmission, as envisaged by previous studies (Bonnet and Réquillart, 2013).

The distinction between regular soft drinks and diet soft drinks is only possible when using regional home-scan data, and specific estimates are not too different for regular soft drinks (an estimated real increase between +4.9% and +5.9%), and suggest an even higher transmission for diet soft drinks (between +6.8% and +13.9%).

Estimates are slightly less consistent for fruit juices, and when Italian prices are used as the conterfactual in equation (1) on the 2011-12 sample they are non-significant. When considering the longer national CPI sample or when using equation (2), the price increase for the aggregate fruit juices category ranges between +2.6% and +5% and is significant, and considering the price of fruit juices (1.46 €per litre in 2011), this would translate into an increase between 3.7 and 7.3 eurocents per litre, hence indicating an incomplete price transmission. Furthermore, if one considers the distinction between non-pure fruit juices (taxed) and pure fruit juices (not taxed), estimates of the real price increase are similar and around +2%, which weakens the evidence that the retail price increase has been generated by the tax, or may indicate that producer strategies have led to price increases to be distributed across the two products. As one would expect, no evidence of a price effect on water has been found with equation (1), which also indicates that estimates from equation (2) can be taken as reliable.

[10] Estimated using the home-scan data, see Table 2.

5.2 Impact on purchased quantities

Table 6 reports various estimates of the tax impact on purchased quantities, using different models and data. If one considers the mere pre-post difference, purchases of soft drinks in France have gone down by around 2.2%, a reduction which only concerns regular soft drinks (-2.1%), whereas diet soft drinks remained stable. Similarly, changes in purchases of fruit juices are very small, and inconsistent with the tax aims, with a minor increase in non-pure (taxed) fruit juices, and a reduction in pure fruit juices. Again, as expected, no change in water purchases is observed, which again suggests that water may act as a valid counterfactual good.

When Italian data from the EuroPanel home-scan data-set are used in the DID equation (1), our findings are not consistent with a health-improving change in purchases, minor and non-significant reductions are observed again for soft drinks, and the only significant effects are a 6.9% increase in the purchases of fruit juices, equally distributed between the taxed and non-taxed soft drinks. Although these effects can be hardly ascribed to the tax, they would be consistent with our previous observation that fruit juice prices have increased less than soft drink prices, hence that the tax may have induced some substitution process.

Given the stability of water prices and purchases, equation (2) in column (c) of Table 6 with water as the counterfactual good should be a reliable estimate. Again, we find a minor reduction in purchases of soft drinks (-1.9%), which can be entirely ascribed to a reduction in regular soft drinks (-1.8%) while all changes for other drink categories are non-significant.

The last column, which refer to the robustness check using Italian data as the counterfactual, but drawn from the Italian HBS, is consistent with the latter estimate (a 2% reduction), but also suggest significant increases in the consumption of fruit juices (+1.7%) and water (+7.3%). On balance, there seem to be good evidence that any impact of the tax on consumption has been small (around -2%) and confined to regular soft drinks.

Table 7 applies the same models to the sub-set of heavy purchasers, intended as those in the top quartile in terms of per-capita purchases of taxed drinks before the introduction of the tax. Although estimates from the various models are not entirely consistent, they are strongly suggestive of a noticeable reduction in purchases of taxed soft drinks for this group. The mere pre-post difference suggests a -11.4% in purchases of soft drinks, mostly because of a reduction in purchases of regular soft drinks (-9.4%), although the reduction is also significant for diet soft drinks (-2.8%). Again, the dynamics of fruit juices do not

Table 6. Tax impact on purchsed quantities, whole sample.

	(a)	**(b)**	**(c)**	**(d)**
Soft drinks	-0.022***	-0.016	-0.019**	-0.020**
	(0.005)	(0.024)	(0.009)	(0.001)
Regular soft drinks	-0.021***	-0.012	-0.018**	-
	(0.004)	(0.023)	(0.008)	
Diet soft drinks	-0.002	-0.008	0.001	-
	(0.003)	(0.011)	(0.008)	
Fruit Juices	-0.009**	0.069***	-0.005	0.017**
	(0.004)	(0.014)	(0.008)	(0.001)
Non-pure fruit juices	0.005*	0.036***	0.008	-
	(0.003)	(0.008)	(0.008)	
Pure fruit juices	-0.013***	0.038***	-0.010	-
	(0.003)	(0.012)	(0.008)	
Water	-0.003	-0.146***	-	0.073**
	(0.008)	(0.047)		(0.000)

(a) Pre-post model with seasonality, no control.
(b) Diff-in-diff with Italy as the control, differential trends, seasonality.
(c) Diff-in-diff with water as the control, common trends, seasonality
(d) Like Model (b), but using data from the Italian HES
Dependent variables are log per capita purchased quantities. * p<0.1; ** p<0.05; *** p<0.01.

seem to follow consistently from the tax, as non-pure fruit juices are unaffected, and a significant reduction is observed for pure fruit juices. Water, as for the full sample, do not exhibit a significant change in purchases.
Estimates from equation (1) in column (b) are non-significant, with the exception of an increase in consumption of non-pure fruit juices. Again, the model based on French data-only and water as the counterfactual good might provide an acceptable identification strategy, given that changes in water purchases emerge as non-significant from the previous models. Here the results are consistent with what found on the full sample, but with larger effect sizes, a 9.7% reduction in purchases of soft drinks, mostly generated by a lower consumption of regular soft drinks (-7.7%). The discrepancy between estimates from equation (1) and equation (2) calls into question the validity of Italian purchases as the counterfactual for this group of consumers, especially because of the relatively small sample size (only 100 Italian households). Thus, it is interesting to look at column (d), which reports estimates of equation (1) using the Italian HES data to build the counterfactual. The reduction in consumption of soft drinks is now even larger (-25.2%), although this larger effect size might also depend on the fact that we do not observe quantities for the Italian households and we must rely on indirect estimates of real expenditures. When looking at the response of fruit juice and water purchases, estimates from the various models are not entirely consistent, but they point towards the lack of an impact.
Taken altogether, estimates for the sub-group of heavy purchasers are suggestive of a significant reduction in purchases of (regular) soft drinks.

5.3 Time patterns in tax effects

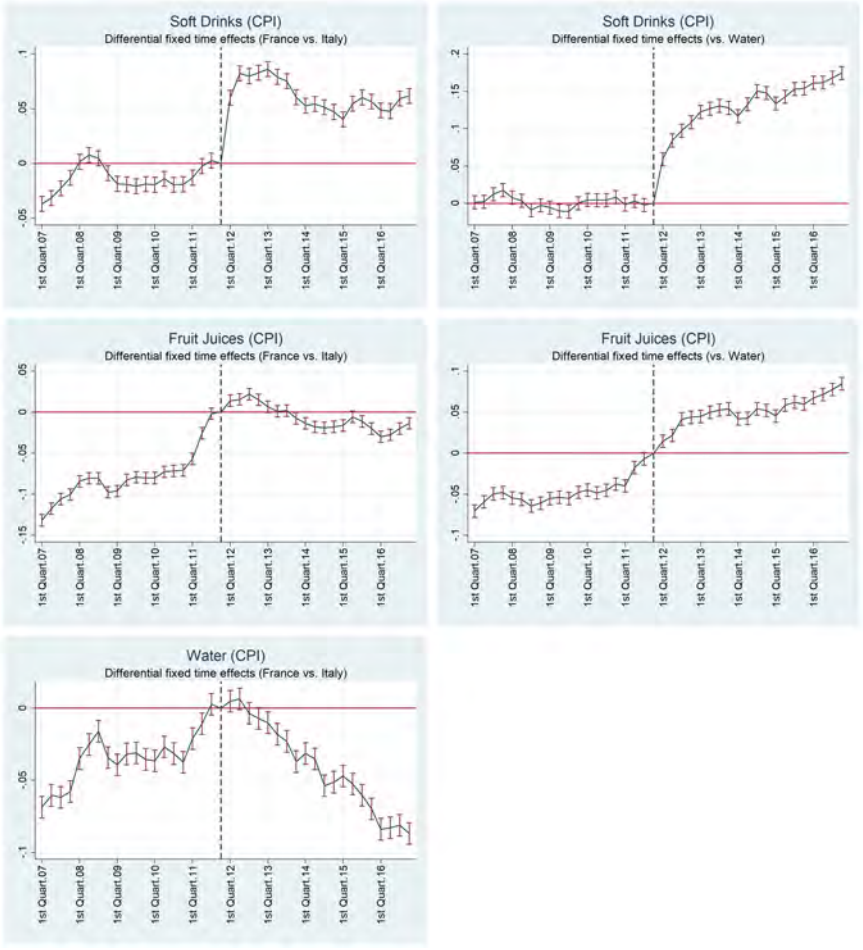
Figure 2 shows a graphical representation of the estimates of differential fixed time effects from equations (3) and (4) for consumer price indices. Both specifications clearly identify the shift in real prices of soft drinks induced by the introduction of the tax in January 2012. Considering Italian consumer prices as the counterfactual, the peak impact is reached by the end of 2012, with a real increase around 8%, then there it reduces to 5% in 2013 and is relatively stable thereafter. Estimates for the fruit juice aggregate confirm the smaller impact as captured by the Difference-in-Difference models, and indicate a sharp increase before the introduction of the tax, then a further short-lived increase.
When the differential fixed time effects are estimated using French data only, and water as the counterfactual good, the timing of the price increases are similar, and both for soft drinks and fruit juices a sharper increase is observed in 2012, but there is no decline thereafter, as prices remain stable or they are even slightly increasing for soft drinks.

Table 7. **Tax impact on purchsed quantities, heavy purchasers**.

	(a)	(b)	(c)	(d)
Soft drinks	-0.114***	-0.003	-0.097***	-0.252***
	(0.012)	(0.050)	(0.018)	(0.001)
Regular soft drinks	-0.094***	-0.027	-0.077***	-
	(0.012)	(0.047)	(0.018)	
Diet soft drinks	-0.028***	0.025	-0.011	-
	(0.007)	(0.022)	(0.016)	
Fruit Juices	-0.035***	0.051*	-0.017	-0.011
	(0.008)	(0.030)	(0.016)	(0.006)
Non-pure fruit juices	0.006	0.041***	0.023	-
	(0.006)	(0.014)	(0.015)	
Pure fruit juices	-0.040***	0.014	-0.023	-
	(0.007)	(0.028)	(0.016)	
Water	-0.018	0.086	-	-0.058***
	(0.015)	(0.093)		(0.001)

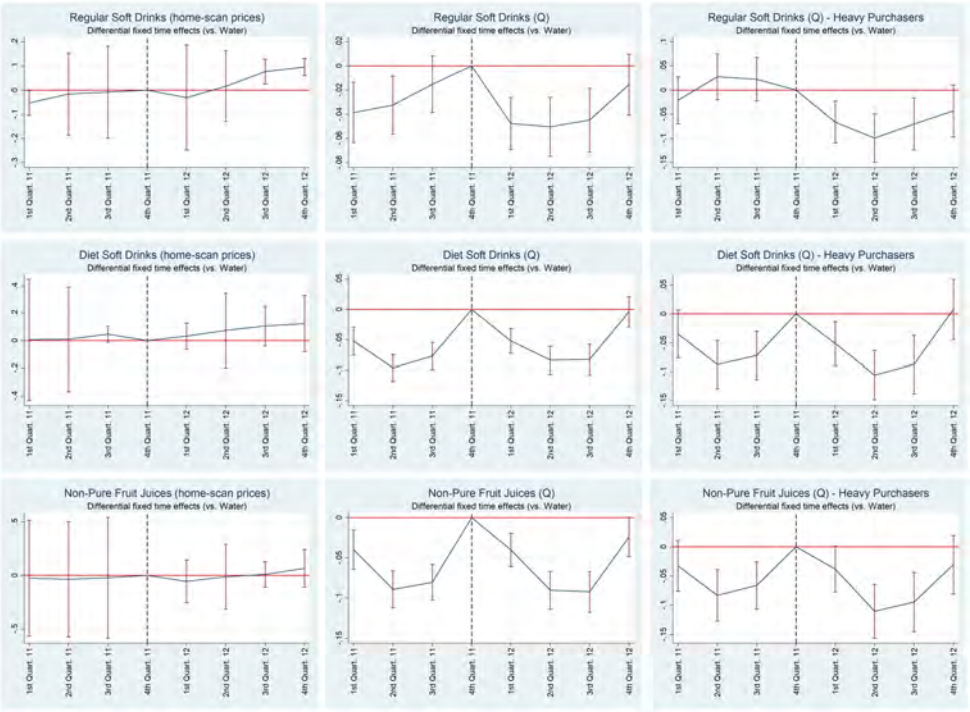
(a) Pre-post model with seasonal effects, no control
(b) Diff-in-diff with Italy as the control, differential trends, seasonality, see equation (1)
(c) Diff-in-diff with water as the control, common trends, seasonality, see equation (2)
(d) Like Model (2), but using data from the Italian HES
Dependent variables are log per capita purchased quantities. * p<0.1; ** p<0.05; *** p<0.01.
Heavy purchasers are defined as households whose total 2011 purchases of taxed drinks lie within the top 25%.

Figure 2: Differential fixed time effects in real consumer price indices, 2007-16



Estimates refer to the differential fixed time effects for France relative to Italy (left graphs) and for each good relative to mineral and spring water CPIs (right graphs) according to Equations (3) and (4), respectively. The effects are relative to December 2011=0, bars show the 95% confidence intervals.

Figure 3: Differential fixed time effects: Prices and purchases of taxed drinks



Estimates refer to the differential fixed time effects for each good relative to mineral and spring water according to Equation (4). The effects are relative to December 2011=0, bars show the 95% confidence intervals.

Full results of the differential time effects models are shown in the Appendix, but some further indications in terms of specific price effects and purchase responses for taxed drinks are summarized in Figure 3. A price increase is observed in 2012 for regular and diet soft drinks, whereas time effects the price of non-pure fruit juices relative to French regions remain non significant through the 2011 and 2012 quarters. Considering the full sample and purchase patterns, time effects for France in 2012 mimic those of 2011, and there is no clear evidence of reduced purchases or changing trends. Finally, the reduction in purchases of regular soft drinks for the heavy consumer group detected by the difference-in-difference model is confirmed by the relative graph in Figure 3, with time effects that are close to 0 and non-significant throughout 2011, and negative and significant in the first three quarter of 2012.

6 Conclusion

The ultimate impact of a soda tax is subject to many elements of uncertainty related to price transmission, firm strategic behaviors and consumer response

and substitution patterns. The existing evidence on this type of measure rests primarily on simulations, but recently there have been several policies that could be evaluated after their implementation. One challenge in these ex post evaluations is the consideration of pre-existing trends and confounding effect, or - under a scientific perspective - the lack of an appropriate control group.
In our assessment of the 2012 French soda tax we address this challenge by referring to a natural control group for French households that were exposed to the introduction of a tax on sweetened soft drinks starting from January 2012. By looking at two regions in France and two neighbouring Italian regions across the border before and after the tax, we open the way to a difference-in-difference estimation of the tax impact. As an alternative specification, we also estimate the tax effects using French data only, but water as the 'counterfactual good' within each household participating in the panel. The availability of panel data on home purchases allows to control for household heterogeneity and non-linear time trends via a fixed effect specification. Under this specification, we have estimated the tax impact on market prices and purchased quantities.
We provide good evidence that the tax - which is applied to producers and importers - has been fully transmitted to consumer prices of soft drinks, while transmission for fruit juices has been partial. The evidence on purchase responses is less clear, there is some evidence of reduction in purchases of regular soft drinks (around 2%), which is reinforced when looking at the sub-sample of heavy purchasers, where the reduction appears to be in the region of 8-10%. All other drink categories do not seem to have been affected by the tax. Suggestive evidence of the (over-)transmission of the French tax to the market prices had been provided by previous studies (Berardi et al., 2016; Bonnet and Réquillart, 2013) and our ex-post evidence confirm these findings. Our analysis of the tax effects on purchases is consistent with some price effect, as the only drinks for which we find an impact on consumption are those whose prices have increased the most. Still, our findings indicate a relatively low elasticity to the tax, as a price effect between +5% and +6% translates into a 2% reduction in consumption. The most interesting result is probably the much larger (per-capita) response by those household who consume larger quantities, which indicates that these taxes may be particularly effective for policy-relevant target sub-groups.
Our data do not allow inference on the longer term effects of the tax, and even with a longer time series it would become difficult to assume that the difference-in-difference model can isolate the tax effect from other confounding factors intervening in the four regions. A further limitation in our study design must be acknowledged, as our data only cover drinks purchased for home consumption, but out-of-home consumption behavior are likely to be very relevant to assess the ultimate weight or health outcome of the tax. Still, our quasi-experimental setting can be compared to other recent ex-post evaluations on

similar fiscal measures in Mexico, Hungary and the city-level tax in Berkeley. Evaluations of these taxes found a complete pass-through and significant reduction in purchases which ranges between 7% and 20%, and our results reinforce the idea that soda taxes may have a meaningful impact on purchases, especially for those groups most at risk.

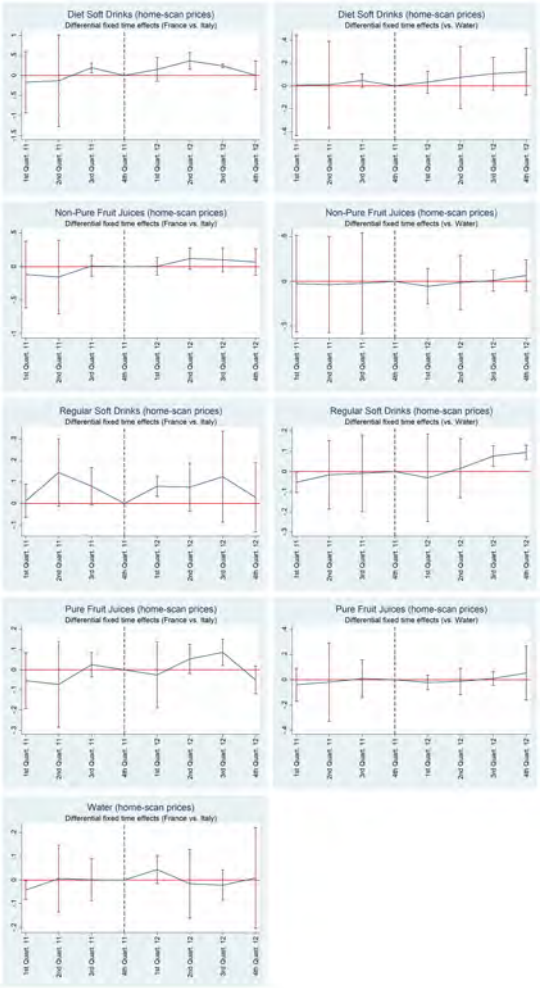
Appendix

Classification of households by socio-economic status

Information on household income is only available for the French dataset. The Italian dataset provides a five-classes classification of households based on a scoring system on socio-economic status, derived from information on home property, possession of durable goods, education level, car ownership and job position. Italian households were classified into the five classes depending on their ranking on the score as follows: (1) top 15%; (2) 65th-85th percentile; (3) 35th-65th percentile; (4) 15th-35th percentile; (5) bottom 15%. We applied the same classification rule to French households (prior to extraction of the regional sub-sets) based on household income.

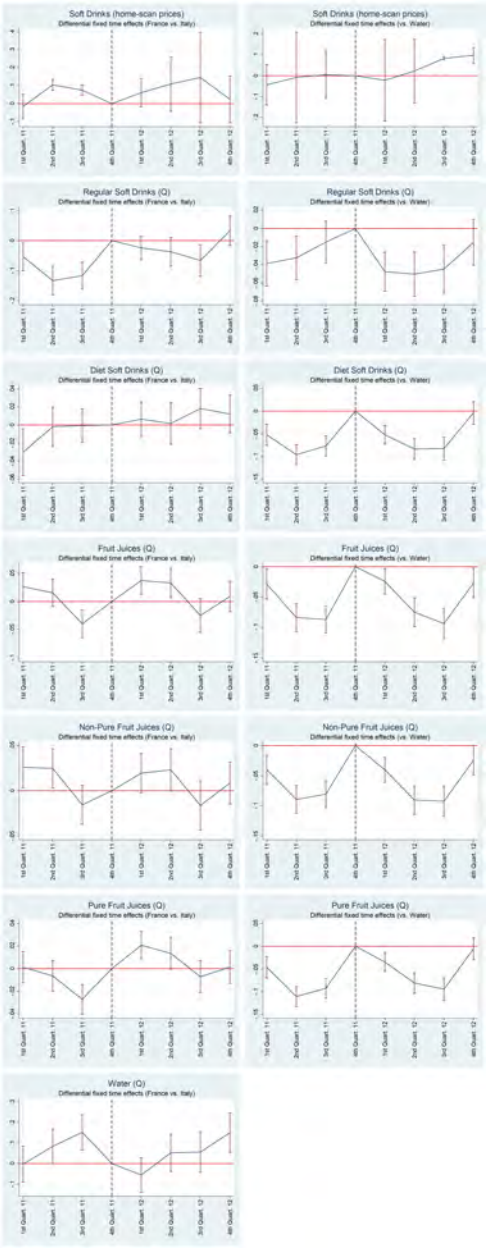
Differential time effect specifications - Full results

Figure 4: Differential fixed time effects: Regional prices from home-scan data



Estimates refer to the differential fixed time effects for French regions relative to Italian regions (left graphs) and for each good relative to mineral and spring water average weekly purchase prices (right graphs) according to Equations (3) and (4), respectively. The effects are relative to December 2011=0, bars show the 95% confidence intervals.

Figure 5: Differential fixed time effects: Purchased quantities



Estimates refer to the differential fixed time effects for French regions relative to Italian regions (left graphs) and for each good relative to mineral and spring water average weekly purchases (right graphs) according to Equations (3) and (4), respectively. The effects are relative to December 2011=0, bars show the 95% confidence intervals.

Figure 6: Differential fixed time effects: Purchased quantites (heavy consumers)

Estimates refer to the differential fixed time effects for French regions relative to Italian regions (left graphs) and for each good relative to mineral and spring water average weekly purchases by heavy consumers (right graphs) according to Equations (3) and (4), respectively. The effects are relative to December 2011=0, bars show the 95% confidence intervals.

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