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Science & Technology in childhood Obesity Policy

Science & Technology in childhood Obesity Policy

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D4.2: Comparative analysis of the impacts of fiscal policies on food and non-alcoholic beverages in Europe

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Science and Technology in childhood Obesity Policy

Abbreviation	Definition
EC	European Commission
EU	European Union
EFSA	European Food Safety Authority
SUSDIET	Sustainable Diets
SSB	Sugar-sweetened beverages
STOP	Science & Technology in childhood Obesity Policy (H2020 project)
WHO	World Health Organization
WP4	Work Package 4 of the STOP project

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1. Introduction

Childhood obesity has become one of the most dramatic features of the global obesity epidemic. The rise in childhood obesity with its long term health risks is of growing concern to public health authorities worldwide. The most significant health consequences of childhood overweight and obesity, include: cardiovascular diseases, diabetes, and musculoskeletal disorders and even certain types of cancers, that often do not become apparent until adulthood (WHO, 2016). In many parts of Europe over 10% of children aged 5-19 are now obese, with overweight affecting up to a third of the children in some countries. While the etiology of overweight and obesity is complex, the increasing prevalence has been widely associated with changes in personal, social, economic and built environments that have shaped individual behaviours increasingly conducive to excessive and imbalanced nutrition, sedentary lifestyles, weight gain and ultimately, diseases associated with it (STOP, 2018). Among these factors, poor diets and nutrition are the leading causes of disease and mortality (The Lancet, 2019). Of the top 20 mortality risk factors in Europe, 12 are related to nutrition and diet (Afshin et al., 2019). While under-nutrition and micronutrient deficiencies still pose an important burden in low-income countries, the largest nutrition-related burden, however, comes from forms of malnutrition characterized by energy-rich and often nutrient-poor or imbalanced but there is discussion on their use)diets, characterized by an excess of foods high in salt and sugar, regardless of income level (STOP, 2018).

In response to rising rates of obesity, governments are attempting to develop strategies to improve diets and thus long-term population health. In principle it involves providing incentives to reduce consumption of foods with negative health weight and health implications and increase those with positive health impacts. Two products groups which have gained attention of public health authorities are: sugars and fruit and vegetables. There is particular concern about the role of sugar-sweetened beverages (SSBs) in children's diets. SSBs are now one of the main sources of sugar intake among children (WHO, 2016), [1] significantly contributing to weight gain and type 2 diabetes (Malik et al., 2013; Imamura et al., 2015). Fruit and vegetable consumption is also receiving much attention as they are recognized as important components of a healthy diet, which if consumed daily in sufficient quantities could help prevent non-communicable diseases such as cardiovascular diseases (He et al., 2006; 2007) and certain cancers (Vainio et al., 2006). Approximately 16.0 million (1.0%) disability adjusted life years (DALYs) and 1.7 million (2.8%) of deaths worldwide are attributable to low fruit and vegetable consumption (WHO/FAO, 2013). The World Health Organization (WHO, 2019) recommends a minimum of 400g of fruit and vegetable per day (excluding potatoes and other starchy tubers); and national recommendations are either close to or above this target. To date, studies from Europe indicate that the majority of children and adolescents fail to reach these recommendations (Yngve, et al., 2005; Diethelm et al., 2012).

Given the health risks and socio-economic costs of the obesity governments are trying to devise policies to improve dietary choices. Fiscal policies, in particular taxes and subsidies are seen as the most efficient way to alter consumers' dietary choices while allowing for consumer choice in a market

[1] The percentage of SSBs' contribution to total sugar intakes was 7% (11%) for children aged 1 to 10 (11 to 17) in France (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, 2017); 22% (33%) for children aged 4 to 10 (11 to 18) years in the United Kingdom (Public Health England, 2018); 17% for children aged 13 to 17 in Spain (Ruiz et al., 2016); 21% (25%) for boys (girls) aged 7 to 18 in the Netherlands (National Institute for Public Health and the Environment, 2011); 5% (8%) for boys (girls) aged 10 to 18 in Italy (Sette et al., 2013). A detailed review of sugar consumption across the world is provided by Newens and Walton (2016).

setting. In an over simplified world taxing a commodity raises its prices and should lower demand while subsidizing a product should lower the price and increase consumption. A common policy recommendation for reducing children's sugar intake is the taxation of SSBs. Numerous countries already tax SSBs (see Global Food Research Program, 2019) and the World Health Organization recommends using taxes on SSBs as a key measure for addressing childhood obesity (WHO, 2016). The use of subsidies to increase fruit and vegetable consumption has not been widely recommended or implemented by governments yet, though there is consistent evidence that this intervention may positively influence dietary behaviours (Niebylski et al., 2015).

The objective of this study is to estimate the effects of these two fiscal policies on children's nutrient intake using data from several European countries. Specifically, we estimate and compare the combined change in the calorie, fat and carbohydrate intakes of children in response to a hypothetical tax increase on sugar-sweetened beverages (SSB) and an equivalent subsidy on vegetable and fruit prices in France, Finland, Italy, Spain, and the United Kingdom.[2] For this assessment, we use demand elasticities for Finland, Italy, Spain, and United Kingdom estimated within the SUSDIET project (ERA-Net SUSFOOD Consortium SUSDIET (2014-2017)[3] and estimate demand elasticities for France while also taking into account income distribution. We then derive nutrient elasticities from own and cross price elasticities by applying a method developed by Allais et al. (2010). These nutrient elasticities embody the sensitivity of a nutrient intake in response to a change in price for a food group – SSB, fruit and vegetable, in our case –, while taking into account the consumer's trade-off between all foods. A change in a particular food price will affect all food quantities demanded through interdependent demand relationships, and thus cause a simultaneous change in the level of nutrient availability. Nutrient elasticities are used to calculate the variations in children's nutrient intake using EFSA consumption data (EFSA, 2011) for the selected five countries. Although it seems intuitive that increasing (decreasing) the price of unhealthy (healthy) foods should discourage (encourage) their purchase, the impact of this price variation on nutrients intakes for the diet overall is not clear, given that food purchases are highly interdependent. There may unintended consequences on nutrient consumption due to substitution and complementarity effects between food products.

Unfortunately, we cannot assess the impact of the two interventions on socio-economically disadvantaged children. As obesity prevalence is highest for the socio-economically disadvantaged (Bann et al., 2018; Lissner et al., 2016), assessing the impacts of these policies on this population would be most useful from a policy perspective, however our data do not allow us to do so. In both data sources, namely price elasticities used from the SUSDIET project and individual consumption data from EFSA, the socio-economic dimension was not available or taken into account. To remedy this shortcoming, we estimate French price elasticities across income classes using the French Kantar home-scan data, and provide an overview of the impact of these measures across different income classes for SSBs and fruit and vegetable. We also summarize any available evidence from previous research regarding direct and indirect effects of these 2 policy measures by socioeconomic status of consumers.[4]

[2] The impact of SSB tax on product recipe is beyond the scope of WP4. It is partly assessed in WP6.
[3] Its objective was to characterize sustainable diets for a sample of the same European countries, using food demand systems similar to the one used in our study.
[4] We exclude low- to middle-income countries due to the varied and often reverse relationship between socioeconomic status and SSB consumption and/or obesity prevalence (Sassi et al., 2018). While Mexico is a middle-income country, studies using Mexico case study are included in the overview. Mexican Household Income and Expenditure Survey indeed reveal a positive relationship between SEP and energy intake from soda (Barquera et al., 2008), as in High-income countries.

Despite this deficiency, this study makes several important contributions to the literature. First, it provides estimates of the impact of a potential SSB tax and fruit and vegetable price subsidy on children's food intakes by considering their complete diet. Previous studies that assessed the effect of fiscal policies on overall diets have estimated the effects on adults' purchase or consumption only (see Cabrera Escobar et al., 2013), although children and adolescents are high consumers of SSBs and low consumer of fruits and vegetables (see ref above). A few studies have however estimated the effect a SSB tax on children's consumption of SSBs (Lin et al., 2011; Cawley et al., 2019). Second, this study proposes a comparative evaluation of fiscal policies on children's diets in several European countries. Previous studies generally assessed their effects for only one country, while in this study, we use a harmonized product classification and estimation methodology to permit cross-country comparisons.

This report is organised as follows Part 2 describes the data and methods of analysis including a discussion of parameters and data limitations; Part 3 presents results of the simulations of a 20% tax on SSBs and equivalent price subsidy for fruit and vegetables and Part 4 provides concluding comments.

2. Data

Two types of data are used in this study: estimated price elasticities, and food consumption and nutrient content data for Finland, France, Italy, Spain and the United Kingdom. Price elasticities for Finland, Italy, Spain, and the United Kingdom elasticities are those estimated in the ERANET SUSDIET project (Akaichi et al, 2017). This project adopted a common aggregation classification across food products to assess diet and a common methodology in the estimation of price elasticities to facilitate the cross-country comparison of results.[5] Overall 16 food categories were constituted: grain products (bread, pasta, rice, wheat flour, and cereals); meat (beef, veal, lamb, and pork); other meats (poultry); cooked meats (ham, pâté, sausages, bacon, etc.); fish and seafood; eggs; animal fat; plant-based fat; fruits and pure fruit juices (fresh, dried and processed); vegetables (fresh, dried and processed); dairy products (milk, cream, butter, yoghurt, dairy desserts, etc.); starchy roots; sugar and similar; coffee, cocoa, tea, infusions and water; soft drinks (sodas, lemonade, fruit flavoured still drinks, flavoured water, iced tea etc.); and composite dishes (pizza, sauerkraut, cassoulet, etc.). Nevertheless, there are several differences in the number and composition of food categories. In particular for our targeted food categories, SSBs were grouped with sugar and confectionary, and prepared desserts for Italy and Spain; and fruit and vegetable juices were not integrated for Finland in fruit category. For the case of France, we estimate price elasticities using the French Kantar World Panel home-scan dataset (Kantar, henceforth), which provides detailed information of products purchased. This detail allows each product to be uniquely identified by quantity purchased, price paid, transaction date, and a rich array of household demographic variables, in particular income classes. The households are selected by stratification according to several socioeconomic variables, and remain in the survey for a mean period of four years. Our data cover the period 2009-2016. We follow the composition of the food category defined in SUSDIET project, except that we group animal and plant-based fat in one group. Methodology and summary statistics are provided in annex 1.

The second source of data is a consumption and nutrient (calorie, carbohydrate, and fat) database,

[5] The British, Spanish and Swedish teams in SUSDIET relied on detailed data from panels of consumers collected by market research companies (Kantar, GfK), while the Finnish and Italian teams used less detailed household budget survey data collected by national statistical institutes.

the EFSA Comprehensive Food Consumption Database, from the European Food Safety Authority (EFSA, 2011).[6] It provides individual dietary intake information over wide variety of food categories, built up from existing food consumption surveys throughout Europe. In an effort to homogenize and harmonize the data from different countries and surveys, EFSA coordinated a uniform methodological guidance for data collection, including but not limited to common stratification and sampling, food categorization, and nutrition composition, etc..The current EFSA Comprehensive Food Consumption Database contains survey data from 32 countries with varying number of subjects and age coverage, spanning from 1997 to 2008. We use the product description information for food groups both by following the food categorization scheme built and advocated by EFSA, called FoodEX2,[7] and the SUSDIET definitions of food categories for each country. Unfortunately, no socioeconomic variables were available for our 5 selected countries.

We limit our analysis to food consumption by children from Finland, France, Italy, Spain and the United Kingdom. This allows us to make use of price elasticities estimated using a common method. Table 1 presents summary statistics for SSB, fruit and vegetable, the three food groups in our fiscal scenarios. For a more detailed coverage, we refer the readers to the EFSA website.[8] The table presents for our three food products, the daily consumption in calories, fat and carbohydrate and their contributions to total caloric, fat and carbohydrate intakes by country and age group category (other children and adolescents).

SSB appears as major contributor to the energy intake for children 3 years or older. The contribution of SSBs to total carbohydrate intake is by far the highest among adolescents in the United Kingdom (7%), but much less so in other countries, varying from 3.9-5.5%. The contribution of fruit and vegetable to total energy intake falls sharply during the period of adolescence in the United Kingdom, from 3.9% for children under 9 years to 2.8% for those over 9 years, on average. This contribution is equal to 3.8% for Finnish adolescents, 4% for Spanish and Italian adolescents and 1.7% for French adolescents. It also keeps decreasing over age, except in Finland where it remains around 3.8%. Moreover, assuming 1g of fat generates 9 Kcal of energy, the contribution of fat consumption to the total energy intake across countries and age groups varies from 30% to 42%. The high level of daily total calorie for Spanish adolescent reported in the Table 1 may be explained by the limited number of observations in the sample.

[6] Only these nutrient intakes were available in the EFSA database.
[7] We retained 17 of 20 FoodEx2 food groups, leaving out dietetic, supplementary and alcoholic beverage categories as the subjects of this study are children.
[8] For a more detailed information on food and nutrient consumption see, EFSA website at http://www.efsa.europa.eu/we refer the readers to the source.

Table 1. Summary statistics: Sugar sweetened beverages (SSBs), fruit and vegetable contribution to daily nutrients intakes (Source EFSA data).

Country	Food groups	Nobs	Energy Kcal	%[1]	Fat g	%[1]	Carb g	%[1]	Nobs	Energy Kcal	%[1]	Fat g	%[1]	Carb g	%[1]
		Other Children: from 36 months up to 9 years							*Adolescents: from 10 up to 17 years*						
Finland	Total		1639	100	54	100	210	100		2166	100	73	100	271	100
Finland	Vegetables	747	19.44	1.19	0.20	0.38	2.97	1.42	306	30.16	1.39	0.34	0.47	4.41	1.63
Finland	Fruits	726	42.40	2.59	0.23	0.43	8.22	3.92	272	52.55	2.43	0.44	0.61	10.14	3.73
Finland	SSB	235	28.02	1.71	0.01	0.01	6.82	3.25	178	61.47	2.84	0.00	0.01	14.95	5.51
France	Total		2031	100	85	100	236	100		2375	100	96	100	280	100
France	Vegetables	477	19.61	0.97	0.30	0.35	3.19	1.35	967	21.98	0.93	0.35	0.36	3.50	1.25
France	Fruits	441	38.52	1.90	0.36	0.42	8.10	3.43	833	41.52	1.75	0.45	0.47	8.57	3.06
France	SSB	290	38.91	1.92	0.04	0.05	9.52	4.03	638	55.32	2.33	0.05	0.05	13.56	4.83
Italy	Total		3002	100	120	100	387	100		3526	100	147	100	440	100
Italy	Vegetables								247	41.85	1.19	0.59	0.40	6.52	1.48
Italy	Fruits	173	67.26	2.24	0.37	0.31	15.98	4.13	214	77.27	2.19	0.61	0.41	17.90	4.07
Italy	SSB	64	35.65	1.19	0.01	0.00	9.51	2.46	109	63.35	1.80	0.00	0.00	16.96	3.86
Spain	Total									4515	100	208	100	468	100
Spain	Vegetables								86	41.16	0.91	1.03	0.49	4.82	1.03
Spain	Fruits								68	113.7	2.52	1.18	0.57	22.49	4.80
Spain	SSB								30	91.96	2.04	0	0	22.99	4.91
UK	Total		2312	100	92	100	301	100		2922	100	115	100	367	100
UK	Vegetables	586	24.57	1.06	0.63	0.69	3.58	1.19	602	33.03	1.13	1.21	1.05	3.65	0.99
UK	Fruits	601	64.85	2.80	0.24	0.27	15.78	5.24	481	47.65	1.63	0.16	0.14	11.63	3.17
UK	SSB	574	37.89	1.64	0.00	0.00	9.97	3.31	607	96.71	3.31	0.00	0.00	25.52	6.96

[1] Contribution to total calorie, fat or carbohydrate

3. Results

3.1 Demand price elasticities

To compares the impacts of taxes and subsidies on food consumption across the selected countries, we rely on the price elasticities estimated by SUSDIET project except for France where these are estimated using a similar model but incorporating income classes following Allais et al. (2010). The own-price elasticities for SSBs, fruit and vegetables are reported in Table 2. For the exposition simplicity and brevity, we do not report all cross-price elasticities, but only comment on those that are significant in the subsequent paragraphs.[9]

As expected, these foods are all normal goods with negative and significant own-price elasticities. But with no evidence of any specific pattern across products or countries. We do note that for France all 3 products are elastic (greater than 1), which is also the case for SSBs in the UK and Italy, and for vegetable in Spain. Products with elastic demands are good targets of fiscal policies as government can get a bigger change in demand for a given price change. Thus, in France and Spain with elastic demand a subsidy of 10% for fruits and vegetables, all else being equal, the subsidy should increase consumption by 10.3% a very modest increase. Similarly, own-price elasticities for fruits range from -1.03 (France) to -0.49 (Finland) indicating that in France a price subsidy for fruits could be efficacious to induce higher consumption compared to our other countries. Other research on fruit and vegetable elasticities often find lower values than ours. For example, Powell et al. (2013) report that across 4 studies, the mean price elasticity was -0.49 for fruits, ranging from -0.26 to -0.81, and -0.48 for vegetable, ranging from -0.26 to -0.71, while Green *et al* (2013) find similar magnitude of elasticities for fruit and vegetable: -0.53 − Harding and Lovenheim (2017) find as us that fruit and vegetable responses to be more elastic, with elasticities that range from -0.83 to -1.38. Our estimates for France, as for Harding and Lovenheim (2017), are derived from much larger price variations and over a longer period of time, and employed instruments that more credibly overcome problems associated with price endogeneity. These differences likely explain any divergence of our elasticity estimates from those in the existing literature.

The own-price elasticities of SSBs are negative and vary substantially, ranging from -1.98 (Italy) to -0.17 (Finland). As before, the countries with higher elasticity – Italy, France and the United Kingdom, are potentially more sensitive to a price hike than the rest of the sample. For Italy, France and the United Kingdom, price elasticities are greater than one thus an SSB tax could in principle be efficacious to reduce SSB consumption. In their review of own-price elasticities for SSBs, Andreyeva et al. (2010) report elasticities that range from -1.0 to -0.8. Cabrera Escobar et al. (2013) report a slightly higher range of -1.09 to -1.51 and in Allcott et al. (2019), the SSB elasticity is about -1.4. The wider range of our estimates could be attributed to the food aggregation levels, as the main outlier in our analysis – Italy with an elasticity of -1.98, may be due to combining sugary and confectionary products with SSBs.

[9] Cross price elasticies are available upon request from any of the SUSDIET participants or the authors of the French study.

Table 2. Own-Price Elasticities

Country	Food Group	Own-Price Elasticity	Food Group	Own-Price Elasticity	Food Group	Own-Price Elasticity
Finland	Vegetable and vegetable products	-0.526	Fruit	-0,492	SSB	-0.171
France	Vegetable and vegetable products	-1.030	Fruit, fruit and vegetable juices	-1,034	SSB	-1.145
Italy	Vegetable and vegetable products	-0.793	Fruit, fruit products and fruit and vegetable juices	-0,924	Sugar and confectionary and prepared desserts + SSB	-1.983
Spain	Vegetable and vegetable products	-1.033	Fruit, fruit products and fruit and vegetable juices	-0,869	Sugar and confectionary and prepared desserts + SSB	-0.846
UK	Vegetable and vegetable products	-0.488	Fruit, fruit products and fruit and vegetable juices	-0,79	SSB	-1.117

Demand price elasticities and income classes

We also estimate price elasticities across income classes for France using a socioeconomic classification of the households constructed by Kantar. This variable is based on a household's monthly income with respect to its number of members and to consumption units defined by the Organisation for Economic Co-operation and Development (OECD). This classification scheme comprises four categories of income: well-off, those households with the highest levels of income (above €3,000); average upper, households whose income is above the national average (between €2,000 and €2,999); average lower (between €1,000 and €1,999), households whose income is below the national average; and modest, households with low income levels (below €999). They are displayed in Table 3. We find that price sensitivity decreases as income rises for SSBs. Thus, modest-income households are significantly more sensitive to price in consumption of SSBs than well-off households. The former are also more sensitive to price than well-off households for fruit and vegetable, but the difference is not significant.

Table 3. Own-Price Elasticities across income class for France

Country	Income class	Vegetable and vegetable product	Fruit, fruit and vegetable juice	SSB
France	Well-off	-1.030	-1.029	-1.135
France	Average upper	-1.031	-1.031	-1.144
France	Average lower	-1.033	-1.036	-1.205
France	Modest	-1.034	-1.041	-1.277

Overall, the result that **modest income households would be more sensitive to changes in the price of SSBs than well-off households** therefore seems more meaningful for considering efficiency of policies. It would result that modest income households would reduce SSB consumption in higher proportion than well-off households when price rises. This has major consequences on the quantity consumed of SSBs by modest income households. Because modest income households usually consume greater amounts of SSBs, the absolute amounts of their reductions would be much larger than those obtained for the well-off households, and the health benefits generated would be largest.

A number of studies have explored quantitatively the link between income and consumers response to price changes, own and cross price elasticities, through different modelling approaches. Data, methodologies and findings of a selected set of these studies focusing on price elasticities for SSBs, fruits and vegetables across income classes are presented in Table 4. Five studies out of eleven (Dong and Lin, 2009; Finkelstein et al., 2010; Huang and Lin, 2000; Lin et al., 2011; and Zhen et al, 2011) find that modest income households are less sensitive to price than well-off households. Green et al (2013) in their systematic review also find similar results (see Table 3 in Green et al, 2013)[10].

However, all these studies do not correct for price endogeneity. One exception is Lin et al. (2011), but the efficiency of their instrument, monthly temperature, to isolate quasi-random price variation

[10] In particular, the own-price elasticities for fruit and vegetable are estimated to be -0.86, (95% confidence interval -0.97 to -0.76) among modest income households v.s. -0.73 (95% confidence interval -0.84 to -0.62) among well-off income households (-0.87, 95% confidence interval -1.06 to -0.70, v.s. -0.73, 95% confidence interval -0.91 to -0.55, for sweets, confectionery, and sweetened beverages).

can be questioned. Another exception is Allais et al. (2010) for fresh vegetables. [11] However, ignoring price endogeneity biases price elasticity estimates, and can sometimes even generate positive correlations between price and quantity demanded. Price endogeneity can arise from both consumers' decisions and price retailers' strategies. Low-income households often pay a lower price for food than high-income households. A variety of reasons such as the shopping place chosen, the allocation of time to find food promotions, to cook, often unobserved by the econometrician, can explain this fact. Second, retailers naturally charge higher prices for higher-quality goods, as well as higher prices for the same good in periods of high demand.

Substitution and complementarity patterns

The effects of fiscal policy measures are determined not only by the degree to which consumers respond to a price change, as described above, but also by the trade-offs that consumers make in response to the change in price. When consumers cut back on sugar-sweetened beverages due to the tax or increase their consumption of fruits and vegetables due to the price subsidy, they may also raise or lower their consumptions of other unhealthy goods. Analysing the substitution/complementarity patterns among products is therefore crucial to assess how fiscal policy affects purchase and consumption overall.

Our analysis does not show any common patterns of significant product substitution/complementarity across the 5 countries examined; Finland, France, Italy, Spain and the United Kingdom.[12] Most of our cross price elasticities are inelastic, that is less than one and generally quite small with absolute values between 0.02 to 0.56. We only comment on some of those that are statistically significant. For example, we find that decreasing the price of vegetables significantly increases consumption of starchy vegetables in Finland (-0.07) and the United Kingdom (-0.09) but decreases their consumption in Spain (0.29). Decreasing vegetable prices also significantly increases meat consumption in United Kingdom (-0.10 for beef; -0.09 for pork; -0.16 for poultry) and Spain (-0.13 for beef; -0.21 for pork), as these are complements in consumption. In France, decreasing vegetable prices significantly increases the demand of red meat (-0.10) and SSB (-0.09). We find, as in Bertail and Caillavet (2008), a substitution between fruit and vegetables in France (0.22). Regarding the impacts of decreasing the price of fruit, we find that the purchase of meat increase in Spain (-0.24 for beef; -0.06 for pork; and -0.10 for poultry). In France, increasing fruit prices would cause an increase in milk products (-0.56) and SSBs (-0.06) purchases.

Regarding the impacts of increasing the price of SSBs, we find that the category of fruit, fruit products and fruit and vegetable juices, and SSBs are substitutes in children 's diets, except in the United Kingdom (-0.08) and Finland (no significant). However, the magnitude of the effects is weak (around 0.02). We also find that SSBs are a substitute for milk products in France (0.15), Italy (0.12) and the United Kingdom (0.04); and snack products in Spain (0.15). In France, we also find a significant substitution with red meat (0.10).

As cross price elasticity numbers are quite small in general, the final impacts can only be had in examining the aggregate impact of the change. Nutrient price elasticities presented in next subsection provide the impact of price changes on total dietary consumption through variations in nutrient intakes.

11 Mhurchu et al. (2013) also find that modest income households have a larger elasticity for SSB, fruit and vegetable, although they do not correct for endogeneity. However, they take into account the censored nature of their data in their estimation method.

[12] From an economics perspective a goods are complements if an increase(decrease) in the price of good j causes a decrease(increase) in consumption of good i, while goods are substitutes if an increase(decrease) in the price of good j causes an increase (decrease) in the consumption of good i.

Table 4: Own and cross price elasticities across income class

	Data	Model/Price endogeneity	Food groups	Own-price elasticity (modest; well-off)	Cross-price elasticity (modest; well-off)
Allcott et al (2019 b)	US home-scan data, Nielsen, 2006-2016	Purchase quantity model /Yes, time-varying prices that the same retailer charges for the same beverages at other stores in other counties	All beverages, sugary foods, alcohol and cigarettes (13 food groups)	SSBs : (-1.40 ; -1.34)	SSBs and diet drinks are the unique substitutes: 0.25
Allais et al. (2010)	French home-scan data, Kantar	AIDS/ Yes, quality-adjusted prices	All food and beverages	SSBs: (-0.99; -0.98) Fresh fruit: (ns; ns) Proces fruit: (-0.61; -0.56) Fresh vegetable: (-0.20; -0.44) Proces vegetable: (-0.95; ns)	Substitutions between: SSBs and fruit juice: (0.16; 0.32) Fresh fruit and SSBs: (0.05; 0.04) Proces vegetables and SSBS: (0.06; 0.09)
Bertail and Caillavet (2008)	French home-scan data, Secodip,1997	Finite mixture AIDS /No	All Fruits and vegetables by degree of processing	Fresh fruit: (-1.73; ns) Fruit juice: (-1.22; -1.16) Fresh vegetable: (ns; -0.81) Canned vegetable: (ns; -0.83	Modest income class: substitution effects only between fresh products
Briggs et al. (2013)	UK, Living Costs and Food Survey, 2010	AIDS/No directly but Bayesian approach uses	All food and beverages	SSBs concentrated: (-1.03; -0.91) SSBs non concentrated: (-0.79; -0.85) Diet concentrated: (-1.12; -0.88) Diet non concentrated: (-0.92; -0.89) Fresh fruit: (-1.04; -1.03) Fruit: (-0.52; -0.61) Vegetable: (-0.83;-0.78)	Substitutions between: SSBs non concentrated and fruit juice: (0.14; 0.13) Diets non concentrated and fruit juice: (0.04; 0.08) All SSBs and diets with tea and coffee (very close across income groups)
Colchero et al. (2015)	Mexico, MNHIES cross-sectional surveys, 2006, 2008, 2010	AIDS/No	All beverages and candies, snacks, sugar, and traditional Mexican snacks	SSBs (-1.16; -1.06) Soft drinks (-1.12; -1.06)	NA

Dong and Lin (2009)	US home-scan data, Nielsen, 2004	Purchase quantity model/No	All fruits and vegetables	Fruit: (-0.52; -0.58) Vegetable: (-0.69; -0.57)	NA
Finkelstein et al. (2010)	US home-scan data, Nielsen, 2006	Two-stage analysis (decision on whether to buy/linear quantity model)/No	Regular soda, fruit drinks, sports energy drinks	No detailed results: −1.02 for households in the 50% to 75% income quartile to −0.49 for the 0% to 25% income quartile of households	NA
Huang and Lin (2000)	Nationwide Food Consumption Survey (1987-88)	Purchase quantity model/No	All food and beverages	Fruits : (-0.65; -0.75) Vegetables: (-0.70; -0.71)	NA
Lin et al. (2011)	US home-scan data, Nielsen, 1998-2007	AIDS /Yes, use monthly temperature	All beverages (SSBs, milk, coffee/tea	SSBs: (-0.9; -1.3) Diet SSBs (-0.7 ; -0.5)	Substitutions between: SSBs/fruit juice: (0.16; 0.25) SSBs /diet SSB: (-0.08; 0.06)
Mhurchu et al. (2013)	New Zealand National household economic surveys (07/08;09/10)	Two-stage analysis (decision on whether to buy/quantity: AIDS)/No	All food and beverages	SSBs (-2.2; -1.26) Fruit: (-0.8; -0.7) Vegetable: (-1.1; -0.6)	Not documented, but cross-price-elasticities are less than zero
Zhen et al. (2011)	US home-scan data, Nielsen, 2004-2006	AIDS/No	All beverages (SSBs, milk, coffee/tea)	SSBs: (-1.06; -1.54)	No significant substitution between beverages

Note: “ns” stands for no significant elasticities, “SSB” for Sugar Sweetened Beverage and “proces” for processed.

These rather disparate findings are also found in the numerous other studies on the topic of price elasticity and food demand. Indeed, there is very little agreement in the literature on common substitution patterns, and sometimes unexpected substitutions are estimated. This is possibly due to the challenges in data quality, variation in identification strategies, and different modelling approaches. Table 4 (last column), summarizes the substitutions/complementarities between SSBs, fruits and vegetables. For example. Lin et al. (2011) find that SSBs and diet drinks are substitutes for well-off households but complements for modest income households. Whereas Allcott et al. (2019 b) find these two beverage categories are substitutes, but do not present any income class effects. Allais et al. (2010) and Lin at al. (2011) find that SSBs and fruit juices are substitutes, but such substitutions are stronger for well-off households than for other income groups. Regarding fruits and vegetables, Bertail and Caillavet (2008) find substitution effects only between fresh fruits and fresh vegetables for modest income households. Allais et al. (2010) estimate that fresh fruits and processed vegetables are substitutes, and the substitution is larger for well-off households. Briggs et al. (2013a) do not find any significant substitution between fruits and vegetables. If we extend the analysis to the substitution patterns between food categories, conflicting and sometimes counterintuitive results exist. Although it is plausible to think that fresh fruits and high content salt-fat products could be substitutes for SSBs (Allais, et al., 2010; Duffey et al. 2010), significant substitutions between SSBs and canned soups (Finkelstein et al., 2013), or between fresh fruits and salt-fat products or cheese may be questionable. Briggs et al. (2013a) find significant substitutions only within beverage categories, but not with foods, while Mhurchu et al. (2013) find that all food categories are complements. The diversity of substitutions and complementarities found indicate that food choices and their determinants remain complex and diverse across time and countries.

3.2 Nutrient price elasticities

To assess how taxes and subsidies on specific foods affect the nutrient composition of the diet, we estimate nutrient elasticities. These measure the change of the calories, fats and carbohydrates in the diet for change in price of vegetables, fruit and SSBs due to either a tax or subsidy. The relationship between the nutrients and food prices has been identified in the literature notably by Huang (1996) and Allais et al. (2010) who show that the demand elasticities can be combined with the nutritional composition of food to derive the price elasticity of each nutrient n. The nutrient n elasticity to food category j price, NUT_{nj} is computed as follow:

$$NUT_{nj} = S'_n \times \varepsilon_j,$$

where ε_j is a (J x 1) vector whose element ε_{ij} is the price elasticity of food group i with respect to food group j price. $S_n = (S_{nj}, j = 1, \ldots, J)$ is a vector where S_{nj} stands for the jth food group's contribution to the *n*th nutrient, so that $\sum_{j=0}^{J} S_{nj} = 1$. Thus, NUT_{nj} summarizes the change on the consumption of the nth nutrient in response to a change in the jth food price. Note that a change in the price of any given food affects all food quantities demanded through the interdependent demand relationships and thus causes a simultaneous change in the levels of nutrient intakes. A detailed discussion of this derivation is presented in Allais et al. (2010). In our study, the S_n vector summarizes the contributions of the J food categories to total calorie, fat or carbohydrate intake calculated using EFSA data. These are reported for fruit, vegetable and SSB in Table 1 (columns denoted with %). Below S_n is calculated for all children and adolescents. We focus on adolescents as a special age group of all children in analyzing nutrient intake as it is a period of major dietary changes for them: they drink more SSBs and eat less fruit and vegetables compared to earlier childhood (see Table1).

3.3 Policy simulations

We examine the impacts of taxes and subsidies on nutrition content of diets for all children and adolescents by simulating a 20% tax on SSBs and equivalent subsidy for fruit and vegetables. The value of the tax and subsidy was chosen based on recommendation of the British Medical Association to the government to introduce a 20% tax on sugary drinks to subsidise the cost of fruit and vegetables (Torjesen, 2015). In Table 5, we report the results of these simulations in terms of the percentage change in calories, fats, and carbohydrates on intakes for all children and adolescents. Given how nutrient elasticities are constructed, the percentage quantity change in nutrient n caused by a price variation τ in food category j is equal to τNUT_{nj}. If the fiscal policy affects a subset I of food categories, then the latter value is equal to $\tau \sum_{j \in I} NUT_{nj}$. Nutrient price elasticities are not reported in Table 5, but they can be deduced from the magnitude of the percentage of quantity divided by τ. [13] Nutrient elasticities are found to be inelastic in our study as in other research. One can also assess the percentage of change in nutrient content brought about by alternative tax and subsidy rates. For instance, applying a 10% tax effects would be halved compared to the 20% tax or subsidy.

We expect that a subsidy of fruit and vegetable prices would, all else equal, increase consumption of fruit and vegetables by substituting away from other foods. Considering that fruit and vegetables are generally associated with lower levels of energy and fat, this should translate into decrease in calorie and fat intakes. Of the five countries examined, the expected effect however occurs for all children only in Italy, and Finland with -2.1% and -0.5% calorie reductions and -3.8% and -1.9% fat intake reductions respectively. France and Spain however exhibit unexpected increases in fat and carbohydrates intakes. The increase in fats may likely be due to an increase of SSB and milk product consumption in France, and all meats in Spain, as highlighted in the substitution and complementarity patterns analysis above. In the United Kingdom there is almost no impact on caloric intake of children though fats are reduced, while there is slight increase in calorie intake for adolescents, mainly explained by an increase in carbohydrates intakes and a smaller decline in fat consumption than for all children (-0.5% vs. -0.8%).

We find that a 20% increase of the SSB prices results in much larger effects than either of the fruit and vegetable price subsidy on carbohydrates in all countries and greater declines in caloric intakes in the UK, Finland and France with relatively larger declines for adolescents. Carbohydrate intakes fall by -1.98% in Finland; -5.21% in Italy; -0.50% in the United Kingdom and -1.81% in France. The fall in carbohydrate intake in the United Kingdom is minimal given the contribution of SSBs to carbohydrate intake is among the highest among our 5 countries. In response to SSB price increase children in France and Italy increase their fat intakes, while Finish, Spanish and British children decrease theirs. The former variations are explained by an increase in the consumption of milk products both in France and Italy (see the substitution and complementarity patterns analysis above. When we combine the two policies to derive a net effect of the policies, there is a drop in the caloric intake for children, ranging from -0.54% (UK) to -2.13% (Italy), and for adolescents from -0.35% (UK) to -2.35% (Italy). France again is an outlier among the five countries, only France experiences an

[13] The combined nutrient price elasticities of fruit and vegetable are obtained using this calculation. The complete set of nutrient price elasticities is available upon request from the authors.

increase in caloric intake (0.49% for children and 0.35% for adolescents linked to the increase in fat intakes of 2.46%, and 2.43% respectively. French children appear to substitute SSB, fruit and vegetables with red meat and milk products which have a higher fat content on average. Results confirm our expectations when both a tax on SSBs and subsidy to fruit and vegetables in applied for all countries except for France. Overall, the net effect of the policies decreases intakes of fat, carbohydrates and calories, except for France.

Impact of the fiscal policies across income class

We also analyse the impact of SSB tax, and fruit and vegetable price subsidy across income class for France using the socioeconomic classification of household defined above. We qualitatively find similar results as for the average French household, but the magnitude of the effect varies across income class. Table 6 shows that decreasing the prices of fruit and vegetable increases calorie, fat and carbohydrate intakes across all income groups (due to the increase in the purchases of SSBs and milk products as for the average household). The policy's impact are less negative on diets for children of well-off households compared to modest ones in the sense that the policies increase consumption of fats, carbohydrates and calories by less than those with modest incomes, (1.89% vs. 2.70% for fats; 2.16% vs. 2.43% for carbohydrates and 1.94% vs. 3.47% for calories. The effects are qualitatively the same for children and adolescents, except that the magnitude of the increases is smaller for adolescents whatever the income class.

We find that a tax on SSBs would be more efficient in improving the quality of the diet of modest income households than other income groups. We estimate that the fall in caloric intake would be greater for modest income households than for well-off income households (-1.84% vs. -1.66%), although the increase in fat intakes is greater in the former (0.20% vs. 0.14%). This is due to greater decrease in carbohydrate intake for modest income households (-4.59% vs. -4.13%). These effects are stronger for adolescents whatever the income class. The impact of applying both an SSB tax and a subsidy to fruits and vegetables does not have the expected negative impact on calories, fats, or carbohydrates over any of the income classes for children or adolescents. As it was highlighted before, French children of each income class substitute SSB, fruit and vegetables with red meat and milk products which have a higher fat content on average.

Table 5. Percentage of quantity change in calorie, fat and carbohydrate intake for all children and adolescents if SSBs tax, fruit and vegetable price subsidy of 20% was implemented

		All children			Adolescents		
Country	Nutrients	Fruit vegetables Subsidy Effect	SSBs Tax Effect	Both Policies Effects	Fruit vegetables Subsidy Effect	SSBs Tax Effect	Both Policies Effects
		-20% in price	+20% in price		-20% in price	+20% in price	
Finland	Calorie	-0.482	-1.282	-1.765	-0.382	-1.814	-2.120
Finland	Fat	-1.894	-1.553	-3.447	-1.778	-2.423	-4.120
Finland	Carbohydrates	0.797	-1.504	-0.707	0.993	-1.980	-0.987
France	Calorie	2.234	-1.742	0.493	2.156	-1.812	0.345
France	Fat	2.301	0.162	2.463	2.258	0.176	2.434
France	Carbohydrates	2.551	-4.399	-1.848	2.478	-4.456	-1.978
Italy	Calorie	-2.097	-0.029	-2.127	-2.271	-0.080	-2.352
Italy	Fat	-3.845	3.655	-0.189	-3.885	3.812	-0.073
Italy	Carbohydrates	-0.299	-4.960	-5.259	-0.695	-5.211	-5.907
Spain	Calorie				1.980	-2.988	-1.008
Spain	Fat				1.412	-3.172	-1.760
Spain	Carbohydrates				2.431	-2.500	-0.069
UK	Calorie	-0.047	-0.496	-0.543	0.365	-0.716	-0.352
UK	Fat	-0.823	-0.026	-0.848	-0.539	-0.194	-0.733
UK	Carbohydrates	0.361	-1.631	-1.270	1.001	-2.201	-1.219

We complete the analysis of the impact of SSB tax, and fruit and vegetable subsidy across income classes by extending and updating the systematic review of Backholer et al. (2016). We integrate studies from 2016 onwards as well as those that assess fruit and vegetables price subsidies. This review also complements our previous discussion of price elasticities summarised in Table 4, by focusing on fiscal policy impacts. It is important to note that differences in price elasticity estimates across income groups do not automatically translate to similar differences in food and nutrient intakes. The difference in responses among socioeconomic groups also depends on SSB, fruit, vegetable, and other food products consumed prior to the tax. As in Backholer et al. (2016), we distinguish the modelling studies assessing hypothetical policy changes from studies evaluating existing fiscal policies. A summary of each study's characteristics (data used, and type and level of fiscal policy) and the likely effects of a SSB tax or a fruit and vegetables price subsidy on differences by socioeconomic group in the purchase, consumption of SSB, fruit and vegetable; variation in energy intakes; and health outcome are presented in Table 7.

Our overview of the results from modelling studies confirms the evidence found by Backholer et al. (2016). We also find that both policies lead, in a majority of the studies, to improvements in the quality of diet. Regarding fruit and vegetable price subsidy policy, two out of three studies show an increase in the purchases of fruit and vegetable. However, Nnoaham, et al. (2010) estimate a similar magnitude of effects across income groups. Considering SSB tax, the impacts are globally of a larger magnitude for modest income households.[14] This result can also be relevant even when low-income demand for SSB is less price elastic than high-income demand. For example, Lin et al. (2011) show that a 20% tax on SSB translates into a larger reduction of all beverage energy intake among adults from low-income households compared with adults from high-income households. However, the policy did translate into a reduction of 33 and 45 kcal/day for children from low- and high-income households, respectively. It is noteworthy that all studies, except Briggs et al. (2013a), that include all food and beverages in their analyses show that decreases in energy intake are greater for low-income households than for high-income households.

[14] There are three exceptions. Brigg (2013a) for non-concentrated sugar sweetened drinks, Brigg (2013b), and Zhen et al. (2011) in one estimation procedure.

Table 6. Percentage of quantity change in calorie, fat and carbohydrate intake for all children and adolescents across income class if SSBs tax, fruit and vegetable price subsidy of 20% was implemented in France

France		All children			Adolescents		
Income Class	Nutrients	Fruit vegetables Subsidy Effect	SSBs Tax Effect	Both Policies Effects	Fruit vegetables Subsidy Effect	SSBs Tax Effect	Both Policies Effects
		-20% in price	+20% in price	Net change 20% tax scenario	-20% in price	+20% in price	Net change 20% tax scenario
All	Calorie	2.234	-1.742	0.493	2.156	-1.812	0.345
	Fat	2.301	0.162	2.463	2.258	0.176	2.434
	Carbohydrates	2.551	-4.399	-1.848	2.478	-4.456	-1.978
Modest	Calorie	2.703	-1.840	0.864	2.640	-1.926	0.714
	Fat	2.433	0.204	2.637	2.394	0.214	2.609
	Carbohydrates	3.474	-4.582	-1.108	3.424	-4.721	-1.297
Average lower	Calorie	2.338	-1.749	0.589	2.263	-1.830	0.433
	Fat	2.353	0.170	2.523	2.312	0.179	2.491
	Carbohydrates	2.711	-4.336	-1.626	2.641	-4.468	-1.827
Average upper	Calorie	2.014	-1.682	0.332	1.929	-1.759	0.170
	Fat	2.258	0.128	2.386	2.214	0.136	2.350
	Carbohydrates	2.075	-4.152	-2.077	1.990	-4.277	-2.287
Well-off	Calorie	1.881	-1.656	0.225	1.793	-1.732	0.061
	Fat	2.160	0.135	2.295	2.112	0.143	2.256
	Carbohydrates	1.944	-4.126	-2.182	1.858	-4.250	-2.392

In addition, the difference between the decreases in energy consumption of modest and well-off households is generally greater in the series of studies covering diets overall than when only beverages are included in the analysis. The difference in energy consumption of modest and well-off households in studies in which only beverages are considered is negative (i.e. the fall is larger for well-off households) in Briggs et al. (2013b), not significant in Finkelstein et al. (2010) and equal to 4 kcal/day in Lin et al. (2011). Whereas it ranges from 3.3 to 7.6 kcal/day in Zhen et al. (2014), and 0.95 percentage point in Nnoaham, et al. (2010). The result in the latter studies means that drop in SSB purchase or consumption would not be offset by the increases in purchase and consumption of other sugary foods. Our overview of the results from modelling studies also confirms the evidence found by Backholer et al. (2016) that a tax on SSBs is likely to lead to improvements in population weight of a similar magnitude across socioeconomic groups or of a greater magnitude for lower compared with higher socioeconomic groups.[15]

All these results suggest that modest income households, in terms of SSBs purchase and consumption, and body weight, benefit from taxes on SSBs and support the potential progressivity of the SSB tax found in Allcott et al (2019). These households may even benefit more than high-income households according to Allcott et al (2019). This quantitative evidence and the internality benefits of the tax (i.e. the mitigation of consumer's self-control and time-inconsistency issue, and imperfect information) imply that internality-reduction benefits are highly progressive for modest income households. On the other hand, as modest income households usually consume more SSBs in high-income countries, it means that modest income households pay more tax. However, Backholer et al. (2016) find in the literature a relatively minor difference in the monetary burden of the tax between higher- and lower-income households (0.10–1.0% and 0.03–0.60% of annual household income paid in SSB tax for low- and high income households, respectively, equating to less than $US 5 per year). Putting that evidences together, reinforces the result of **the potential progressivity of an SSB tax** found in Allcott et al. (2019).

We get a less optimistic picture of the impact of an SSB tax for studies evaluating existing SSB taxes in Philadelphia, Berkeley, or Mexico.[16] Since the systematic review of Backholer et al. (2016), six more evaluations of SSB tax impact across socioeconomic strata were published. The evidence found by Backholer et al. (2016) of no significant variation in consumption frequency of taxed beverages for children and adults is again validated by the studies evaluating the SSB tax in Philadelphia and Berkeley. Only Falbe et al (2016) find SSB consumption falls in Berkeley (–21%) in low-income neighbourhoods. However, their analyses are based entirely on repeated cross-sections (as opposed to longitudinal data as in Cawley et al., 2018 or Seiler et al., 2019).

The result of no significant variation in SSB consumption, even for modest households, does not play in favour of the potential progressivity of the SSB tax found in modelling studies. Furthermore, the evidence found by Backholer et al. (2016) of a relatively minor difference in the monetary burden of the tax between higher- and lower-income households is questioned in studies evaluating existing SSB taxes. In particular, Seiler al (2019) estimate that the tax imposes a relatively larger financial burden on low-income households. They are more likely to continue purchasing sweetened beverages even with the tax because they are less likely to engage in cross-shopping. As in Backholer et al. (2016), however there is evidence that children from low-income families are positively affected by the tax in studies evaluating existing SSB taxes. Cawley et al. (2018) find a

[15] Except in Brigg (2013b).
[16] No study was found for fruit and vegetable subsidy policy. To the best of our knowledge, no country has implemented this policy.

significant reduction of added sugars for African-American children (-8.0 g/day) and children who consumed at least one 20-ounce bottle of regular soda each day prior to the tax (-14.7 g /day). The evaluations of the Mexican SSB tax using household scanner data seem more encouraging. Batis et al. (2016), Colchero et al. (2016) and Aguilar et al. (2019) estimate that low socioeconomic status households reduce their purchases of taxed foods by up to 10.2%. However, Aguilar et al. (2019) find that the tax also causes a small but positive effect in total calories purchased of 3.6% due to substitution away from taxed to untaxed foods, though the increase was not statistically significant for modest income households.

Table 7: Impact of a fiscal policy on socio-economic inequalities in SSB, fruit and vegetable purchase, consumption, calorie intake, and various health outcomes

				Outcomes		
	Data	Size and type of policy	Food groups	Variations in purchase or consumption (Modest/Well-off)	Variations in calorie intake (Modest/Well-off)	Health outcomes (Modest/Well-off)
Modelling studies						
Bertail and Caillavet (2008)	France, home-scan data, Secodip, 1997	Subsidy on fresh fruit and vegetables: No level of price decrease specified	All fruits and vegetables by degree of processing	No or modest effect: Only changes in the allocation of purchases between fruit and vegetables, or between fresh and processed products; Well-off groups increase their purchase of fresh vegetables	NA	NA
Briggs et al. (2013a)	UK, Living Costs and Food Survey, 2010	SSB tax: 20% increase in prices (concentrated and non-concentrated)	All food and beverages	Sugar sweetened drink (concentrated): (−15.9%; −15.0%) Sugar sweetened drink (non-concentrated): (−15.2%; −16.8%) Diet soft drink (concentrated): (11.8%; 6.4%) Similar increase in pure fruit juice across income tertiles	Reduction in calorie intake from all foods and beverages kcal/person/day: (-4.6; -5.5)	No significant difference in the prevalence of obesity between income groups
Briggs et al. (2013b)	Ireland, survey on Lifestyle and Attitude to Nutrition, 2007	SSB tax: 10% increase in prices (90% pass-through)	SSBs	NA	Reduction in calorie intake from SSBs (kcal/person/day): (-1.9; -2.3)	Reduction in the prevalence of obese: (-1.1%; -1.4%)
Dong and Lin (2009)	US, home-scan data, Nielsen, 2004	Subsidy on fruit and vegetables: 20% decreases in prices	All fruits and vegetables	Effect on modest only reported (g/person/day): Vegetable: 24.5 Fruit: 15.75	NA	NA
Finkelstein et al. (2010)	US, home-scan data, Nielsen, 2006	Tax on carbonated SSBs; tax on all SSBs: 20% or 40% increase in prices	Regular soda, fruit drinks, sports energy drinks	NA	No statistically significant reduction in calories for households in the lowest- and highest income quartiles	No statistically significant reduction in BMI for households in the lowest- and highest income quartiles

Lin et al. (2011)	US, home-scan data, Nielsen, 1998–2007	SSB tax: 20% increase in prices	All beverages (SSBs, milk, coffee/tea)	NA	Reduction in energy intake (kcal/day): Adults: (-37; -33) Children: (-33; -45)	10-year weight change (kg), adults only: (-1.96; −1·80) 10-year % change in prevalence of obesity (%-points), adults only: (-3.58; -3.46)
Nnoaham, et al. (2010)	UK, expenditure and Food Survey, 2003–2006	Subsidy on fruits and vegetables: 17.5% price decrease	All food and beverages	Fruit and vegetable purchases: (4.75%; 4.75%)	Reduction in energy intake: (-1.53%;-0.58%)	Total deaths (excluding obesity related CVD deaths): ([-327;-627]; ([-323;-571])
Sharma, et al. (2014)	Australia (Victoria State), ACNielsen home-scan panel Data, 2013	SSB (regular soft drinks, cordial and fruit drinks) tax: 20% increase in prices and a 20 cent/Liter tax	All non-alcoholic beverages	_20% tax_: Regular soft drink: (-15.1%; -13.1%) Cordial: (-45.6%; -29.0%) Fruit drink: (-3.1%; -11.8%) _20 cents per liter tax_: Not reported by income	NA	Total net change in weight (kg): _20% tax_: (-0.40; -0.23); _20 cents per liter tax_: (−0·56;−0·35)
Zhen et al. (2011)	US, home-scan data, Nielsen, 2004–2006	SSB tax:	All beverages (SSBs, milk, coffee/tea)	Drops in regular SSB (liter/year): ([-2.45,-3.03];[-2.63,-2.73])	NA	NA
Zhen et al. (2014)	US home-scan data, Nielsen, 2006	SSB tax: 26% increase in prices	All food products	Fall in purchase quantities (liter/quarter): SSB: (-1.9; -1.4) Pure juice: (-0.35; -0.67) Diet drink: (0.12; 0.25)	Fall in daily energy (kcal/person/day): From SSBs: ([-17.5, -16.2]; [-13.9, -12.1]) From all food groups: ([-13.2,-18.2]; [-5.6,-14.1])	NA

Studies evaluating existing SSB tax

Aguilar et al. (2019)	Mexico, home-scan panel dataset, Kantar Worldpanel (2013–2014); Hand-coded product-level nutritional information	Tax on drinks with added sugars in Mexico. January 1, 2014 Tax level: 1 peso per liter tax (corresponding to a 10% price increase)	All food products and beverages	Fall in purchase of sugary drinks: (-6.4%; -8.1%)	Total calorie intake (NS; +0.05%)	NA

Batis et al. (2016)	Mexico, Consumer Panel Services, Nielsen. Jan 2012 to Dec 2014	Tax on nonessential foods (energy density>275 kcal/100 g): 8%; Tax on drinks with added sugars: 1 peso per liter tax (corresponding to a 10% price increase); January 1, 2014	All food products and beverages	Purchases of taxed foods: (−10.2%; NS).	NA	NA
Cawley et al. (2019)	US (Philadelphia), cross-sectional data from consumers at stores; household survey of beverage consumption, 2016–2017	SSB tax in Philadelphia. Taxed beverages: regular and diet soda, sports drinks, energy drinks, juice drinks (less than 50 percent juice), and sweetened tea. June, 2016 Tax rate: 1.5 cents per ounce	All taxed and untaxed (bottled water, and pure juice) non-alcoholic beverages	No significant variation in consumption of added sugars from SSBs and the frequency of consuming all taxed beverages for children and adults; No significant effects of the tax by poverty level, participation in SNAP or WIC, or education; Significant reduction of added sugars for African-American Children (8.0 g/day) and Children who consumed at least 67 grams of added sugars in the baseline period (14.7 g /day); African-American Adult reduces the frequency of regular soda consumption by 14.6 times per month;	African-American : children: -32 calories per day	NA
Colchero et al. (2016)	Mexico, Consumer Panel Services, Nielsen. Jan 2012 to Dec 2014	Tax on drinks with added sugars in Mexico. January 1, 2014. Tax rate: 1 peso per liter tax	All taxed and untaxed (without added sugar) beverages	Consumption of taxed beverages: (−9.1%; -5.6%). Consumption of untaxed beverages: (2.4%; 1.5%)	NA	NA

Falbe et al (2016)	US (Berkeley, San Francisco, Oakland), interviewer-administered beverage frequency questionnaire in, low-income neighbourhood before and after implementation of the tax, (April through July 2014 and April through August 2015)	SSB tax in Berkeley. Taxed beverages: regular soda, sports drinks, energy drinks, juice drinks (less than 50 percent juice), and sweetened tea. Nov, 2014 Tax rate: 1 cent per ounce	All taxed and untaxed (diet soda, bottled water, and pure juice) non-alcoholic beverages	SSBs consumption decreased in Berkeley (–21%) vs. (+4%) in the comparison cities of San Francisco and Oakland (+4%). Water consumption increased more in Berkeley (+63%) than in comparison cities (+19%).	NA	NA
Fletcher et al. (2010)	US, survey from Behavioural Risk Factor Surveillance System (BFRSS), 1990–2006	State-level SSB sales taxes (mean tax rate range 3.5–4.7%)	All taxed and untaxed (bottled water, and pure juice) non-alcoholic beverages	NA	NA	A one percent increase in existing SSB tax rates was associated with decreases obesity by 0.08 pp and overweight by 0.10 pp for low income. For individuals with the highest category of income, the corresponding decreases are 0.05 pp for obesity and 0.08 pp for overweight
Seiler et al. (2019)	US (Philadelphia), cross-sectional data at retail point-of-sale data, IRI (01/2015–09/2018); Local demographic Information; Hand-coded product-level nutritional information	SSB tax in Philadelphia. Taxed beverages: regular and diet soda, sports drinks, energy drinks, juice drinks (less than 50 percent juice), and sweetened tea. June, 2016 Tax level: 1.5 cents per ounce	All taxed and untaxed beverages (bottled water, and pure juice)	Purchase quantity decreases 10% more in the highest-income area relative to the lowest-income area; Demand is more elastic in high income areas	No significant variation	NA

Note: A pass-through is the equilibrium consumer price minus the initial consumer price divided by the price increase due to the tax. A 90% pass-through means that 10% of tax is absorbed by firms. A cordial drink is a non-alcoholic drink that is very sweet and flavoured to taste like various fruits, such as lemon, strawberry, kiwi, and peach. “pp” stands for percentage points.

4. Concluding remarks

Childhood obesity has become one of the most dramatic features of the global obesity epidemic. The use of fiscal policy measures, such as specific food taxes and subsidies to modify food choices and diets in the fight against obesity is widely advocated in academic and public health circles worldwide. The objective of this study was to estimate the effects of fiscal policies – a hypothetical 20% tax increase on sugar-sweetened beverages (SSB) and an equivalent subsidy on fruit and vegetable prices, on children nutrient intakes in five European countries – Finland, France, Italy, Spain and the United Kingdom. To complete our analysis, we also examine the impacts of the tax and subsidy across socio-economic (income classes) categories.

Our results indicate that:

- Modest income households would be more sensitive to changes in the price of SSBs, fruits and vegetables than well-off households. However, mixed substitution patterns, and sometimes unexpected substitutions estimated do not enable us to predict the whole impact of the interventions on the nutritional quality of diet;
- SSB tax generates much larger effects than a fruit and vegetables price subsidy. The SSB tax causes an unmistakable fall in carbohydrate intakes and calories. The magnitude of the reduction in caloric intake however will depend on how much consumers substitute SSBs for high fat products;
- Adolescents and children from low-income families are the children who benefit the most, in terms of reductions in calorie and carbohydrate intakes, from the imposition of a SSB tax;
- The quantitative evidence for children from low-income families; the internality benefits of the tax (i.e. the mitigation of consumer's self-control and time-inconsistency issues, and imperfect information), and the weak monetary burden of the tax resolutely challenge the significance of the regressivity argument commonly put forth to oppose an SSB tax implementation.
- Combining the two policies would generally have the desired effect on calorie intakes.

The evaluations conducted in this report are based upon the extreme assumption that household and child sensitivity to price are the same. This usual assumption is made because there is still no food price elasticity for children in the literature (see Lin et al., 2011). A likely solution would be to estimate children stated preferences using surveys and online or laboratory shopping experiences. However, the analysis would rely on self-reported data about hypothetical purchasing decisions on a limited set of products. Using real purchases would be a preferable way of proceeding. However, food products purchased are generally consumed by all or a part of the members of the household. It is so difficult to assess which quantity is consumed by the child in the household. It results that it is hard to detangle children price sensitivities to those of the whole household.

This issue will be coped with by focusing the analysis on food products specifically marketed to children and so almost exclusively consumed by children. Estimating the demand of these products using food purchases data will provide child's price elasticity. This is the aim of future work in WP4.

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6. Annex

6.1 Demand System Estimation

We estimate the 17-food-group demand system using the quadratic extension of Deaton and Muellbauer's (1980) Almost Ideal Demand System by Banks, Blundell, and Lewbel (1997), for France. In particular, for each household, the budget share for food group $i, i = 1, \ldots, I$, is given by

$$w_i = \alpha_i + \gamma_i \boldsymbol{p} + \beta_i\big(x - \alpha(\boldsymbol{p}, \theta)\big) + \mu_i \frac{\big(x - \alpha(\boldsymbol{p}, \theta)\big)^2}{b(\boldsymbol{p}, \theta)} + u_i \qquad (1)$$

with

$$\alpha(\boldsymbol{p}, \boldsymbol{\theta}) = \alpha_0 + \boldsymbol{\alpha p} + \frac{1}{2}\boldsymbol{p}'\boldsymbol{\Gamma p}$$
$$b(\boldsymbol{p}, \boldsymbol{\theta}) = \exp\,(\boldsymbol{\beta p})$$

where x is the log total household food expenditures and $\boldsymbol{p}$ is the log price vector; $\boldsymbol{\theta}$ is the set of all parameters; and u_i is the disturbance term. Vector variables are boldfaced.

The uncompensated price elasticities are given as the following (Lecocq and Robin 2015):

$$\epsilon_{ij} = \frac{\varepsilon_{ij}}{w_i - \delta_{ij}} \qquad (2)$$

where

$$\varepsilon_{ij} = \gamma_{ij} - \varepsilon_i\big(\alpha_j + \gamma_j \boldsymbol{p}\big) - \mu_i \beta_j \frac{\big(x - \alpha(\boldsymbol{p}, \boldsymbol{\theta})\big)^2}{b(\boldsymbol{p}, \boldsymbol{\theta})}$$

$$\varepsilon_i = \beta_i + 2\tau_i \frac{\big(x - \alpha(\boldsymbol{p}, \boldsymbol{\theta})\big)}{b(\boldsymbol{p}, \boldsymbol{\theta})}$$

and δ_{ij} is the Kronecker delta.

Under the assumption of weak separability of preferences, when a shock is introduced to a price of a food in the system, the shock affects the prices and quantities of the foods in the system, but not those of outside. However, the way households choose to react to price shock could be correlated to quantities demanded through channels other than captured by the controls in our model. It is also possible that our model could be capturing systematic variation between product characteristics and price that is driven by supply and not by demand. This could render potentially endogenous price. We mitigate these concerns by including in our model multiple demographic controls and by including market-time controls, respectively. Specifically, the parameter α_i is modeled as a linear form $\alpha_i = \alpha_{i0} + Z_h$, where Z_h is a vector of household characteristics. We use a number of household-level time-varying variables, such as the household size, income level, marital/couple status and car ownership, as well as individual characteristics of the main shopper – gender, age and education level, to capture as much of the systematic component of food choices as possible.

Foods, in a broad sense, are perhaps the most frequent purchases made by households due to daily consumption and generally perishable nature. More disaggregated food groups, however, are purchased periodically, giving rise to empirical problems of seasonality and missingness in price due to non-purchase. To avoid either, we proceed with aggregating the purchase data annually. For the same reason, we retain only households with at least 10 months of observations per calendar year. As a result, there are 68,468 household-year observations from 18,164 distinct households. The mean unit values and budget shares appear in *Panel a* in Table A. Quite predictably, the food groups of fish and seafood and meats command the highest prices, while the food categories of focal interest in this study – SSB and vegetables are at the opposite end of the price distribution. The budget shares for SSB and vegetables are 0.04 and 0.07, respectively. Regarding demographics, 68.46% of household head are married or live in couple, with a household size of 2.49 persons and 91.08% of the households have at least one car. The mean monthly household income is 2,717 euros. The absolute majority – 85.62%, of the main shoppers are women at an average age of 52.28 year old. To represent the spatial distribution of the sample households, we constructed a region/market indicator binary variables that are an interaction of the 12 administrative regions in the country and an indicator variable of urbanization level of the residence area of each household. The descriptions and simple summary statistics of the variables are reported in Table A, *Panel b*.

Furthermore, we adopt an identification policy that exploits the differential within the prices household pay. For this reason, rather than using the unit values as the price in (1), we construct a variation of the Fisher Ideal price index as developed by follow Zhen et al. (2014):

$$p_{ijt} = \sqrt{\frac{\sum_{I\in D}\sum_{m\in M,i\in I,t\in T} p_{ijt}q_{ijt}}{\sum_{I\in D}\sum_{m\in M,i\in I,t\in T} \overline{p}_{imt}q_{ijt}} \times \frac{\sum_{I\in D}\sum_{m\in M,i\in I,t\in T} p_{ijt}\overline{q}_{imt}}{\sum_{I\in D}\sum_{m\in M,i\in I,t\in T} \overline{p}_{imt}\overline{q}_{imt}}}$$

where p_{ijt} and q_{ijt} are the price and quantity of product i, at time t, purchased by household j, and $\overline{p}_{imt}$ is the market average price for the product i.

Table A. Variable Descriptions and Summary Statistics, French Kantar Panel 2009-2016.

Variable	Description	Mean	St. Dev
Panel a			
UV_1	Unit value for grains and grain-based products	4.10	1.42
UV_2	Unit value for meats	10.35	3.82
UV_3	Unit value for poultry	8.58	3.32
UV_4	Unit value for sausages and processed meats	12.51	4.54
UV_5	Unit value for fish and seafood	11.52	4.89
UV_6	Unit value for dairy products	3.00	1.56
UV_7	Unit value for eggs and egg products	3.34	1.29
UV_8	Unit value for oils and fats	4.63	1.44
UV_9	Unit value for fruit, fruit products and fruit juices and nuts	2.40	1.02
UV_10	Unit value for vegetables and vegetable products	2.34	0.91
UV_11	Unit value for starchy roots, tubers and products thereof, sugar plants; legumes, and oilseeds	1.47	0.85
UV_12	Unit value for sugar and similar, confectionery and water-based sweet desserts	4.94	2.02
UV_13	Unit value for seasoning, sauces and condiments; additives	6.12	3.84
UV_14	Unit value for coffee, cocoa, tea and infusions; water	2.37	4.46
UV_15	Unit value for soft drinks	1.46	0.81
UV_16	Unit value for alcoholic beverages	5.24	3.45
UV_17	Unit value for composite dishes	6.05	2.33
w_1	Budget share for grains and grain-based products	0.09	0.05
w_2	Budget share for meats	0.08	0.05
w_3	Budget share for poultry	0.04	0.03
w_4	Budget share for sausages and processed meats	0.06	0.03
w_5	Budget share for fish and seafood	0.06	0.04
w_6	Budget share for dairy products	0.14	0.05
w_7	Budget share for eggs and egg products	0.01	0.01
w_8	Budget share for oils and fats	0.02	0.01
w_9	Budget share for fruit, fruit products and fruit juices and nuts	0.06	0.04
w_10	Budget share for vegetables and vegetable products	0.07	0.04
w_11	Budget share for starchy roots, tubers and products thereof, sugar plants; legumes, and oilseeds	0.01	0.01
w_12	Budget share for sugar and similar, confectionery and water-based sweet desserts	0.08	0.04
w_13	Budget share for seasoning, sauces and condiments; additives	0.05	0.02
w_14	Budget share for coffee, cocoa, tea and infusions; water	0.04	0.03
w_15	Budget share for soft drinks	0.04	0.03
w_16	Budget share for alcoholic beverages	0.08	0.08
w_17	Budget share for composite dishes	0.07	0.05
Panel b			
Couple	Binary variable = 1 if the main shopper lives in couple	0.6846	0.4647
HHSize	Number of persons living in the household	2.4862	1.3770
Female	Binary variable = 1 if the main shopper is female	0.8562	0.3509
Age	Age of the main shopper, in years	52.28	15.64
Income	The midpoint of the household income category	2716.83	1376.72

Notes: Data source is Kantar WorldPanel 2009-2016. The unit values are expressed per kg or liter.