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THE UNIVERSITY *of York*

WP 26/07

## Shaping Soft Drinks: Sugar Taxes, Consumption, and Reformulation in Europe

Cinzia Di Novi and Paola Salari

May 2026

<http://www.york.ac.uk/economics/postgrad/herc/hedg/wps/>

## Shaping Soft Drinks: Sugar Taxes, Consumption, and Reformulation in Europe\*

**Cinzia Di Novi** (Corresponding author), Department of Economics & Management, University of Pavia, via San Felice, 27100 Pavia, Italy; External Member, Health Econometrics and Data Group (HEDG), University of York, United Kingdom; [cinzia.dinovi@unipv.it](mailto:cinzia.dinovi@unipv.it) – orcid: <https://orcid.org/0000-0002-3536-5507>;

**Paola Salari**; Joint Research Centre, European Commission, Via Enrico Fermi, 2749 - 21027 Ispra, Italy; [paola.salari@ec.europa.eu](mailto:paola.salari@ec.europa.eu).

### Abstract

Sugar-sweetened beverages are a major source of free sugars in Western diets. In response, several European countries have introduced taxes to encourage product reformulation and reduce consumption. This study assesses how these taxes affected sales in off-trade and on-trade markets, examines consumers' potential substitution effects using Euromonitor data (2004–2019), and evaluates manufacturers' reformulation responses through Mintel product-launch data (2010–2019). We focus on six countries that implemented such taxes, specifically Belgium, France, Hungary, Ireland, Portugal, and the United Kingdom, and additionally analyse Denmark, which introduced a similar tax earlier and repealed it in 2014, providing a reverse test case. Using a synthetic control approach, we construct counterfactual scenarios to estimate tax impacts. We find significant sales effects only under progressive tax designs, while reformulation emerged consistently, particularly where sugar thresholds and implementation timelines were clearly defined.

**JEL classification:** H2, H3, I12, I18

**Keywords:** sugar-sweetened beverages (SSBs); unhealthy diets, excise taxes; fiscal policy; consumption patterns; food industry; reformulation; synthetic control method; public health

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\*The authors would like to thank the participants of the seminar at the University of San Marino, in particular Alberto Franci and Pietro Renzi, as well as the participants of the CamRisk Conference 2026 at the University of Pavia, especially Patrizio Tirelli, for their valuable feedback. The authors are also grateful to Unit F1 (Health Promotion Group) of the Joint Research Centre (JRC), European Commission, for their valuable comments and contributions, and for providing access to the Euromonitor and Mintel datasets. In particular, we thank Jan Wollgast for inspiring and supporting this work, as well as Petros Maragkoudakis, Evangelia Grammatikaki, and Ana Sarasa Renedo for their insightful comments and contributions. The authors would also like to thank Dominique Mollet and Professor Scott Burris for discussions on an early version of this work and for their inspiration. An earlier version of this paper was presented at the Italian Health Economics (AIES) Annual Conference in Naples (December 2024). We are grateful to all participants for their valuable feedback, with special thanks to Fabrizio Mazzonna. The views expressed are those of the authors and do not necessarily reflect the opinions of their affiliated institutions.

## Introduction

Improving diets has become a central priority in health promotion strategies across Europe. This focus responds to the growing prevalence of obesity, a multifactorial condition influenced by biological, socioeconomic, and environmental factors, which has brought dietary behaviours under increased scrutiny. In particular, the consumption of energy-dense foods, including foods and beverages high in free sugars, has been linked to weight gain and can contribute to overweight and obesity. Within this context, interventions such as fiscal measures designed to reduce sugar consumption, or policies promoting the reformulation of products containing free sugar to lower their content, are gaining widespread support within the public health community (WHO, 2024).

Excessive consumption of free sugars has well-documented effects on health, particularly through sugar-sweetened beverages (SSBs hereafter) (White, 2008; WHO, 2016; WHO, 2022), which represent a major source of free sugars in Western countries (Fletcher et al., 2015). While the health risks are clear, policy discussions continue regarding the most effective strategies to reduce sugar intake at the population level. SSBs refer to non-alcoholic drinks with added sugars, including carbonated, soft drinks, energy drinks, sports drinks, fruit drinks with added sugar, ready-to-drink teas and coffees, sweetened milk-based beverages, and flavoured waters (World Bank, 2020). These beverages represent a significant source of “empty calories,” providing energy without essential nutrients, and are closely related to poor diet quality, weight gain, and increased risk of adverse health outcomes associated with diet-related non-communicable diseases (NCDs hereafter), including type 2 diabetes (Vartanian et al., 2007; Page et al., 2018; Cornelsen & Smith, 2018).<sup>1,2</sup>

To curb sugar consumption, several European countries have introduced mostly excise taxes on products with free sugars, including SSB taxes. These fiscal measures can incentivize reformulation by increasing the relative cost of sugar for manufacturers (Li et al., 2025). Additionally, when taxes are passed through to retail prices, the resulting price increases can discourage purchases and reduce overall consumption of these products.<sup>3</sup> In this case, these taxes operate as other “sin” taxes and are rooted in the Pigouvian principle (Pigou, 1920). Since excess sugar consumption is a risk factor for

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<sup>1</sup> It has been argued that sugary drinks may contribute more to weight gain than equally sugary foods, as calories in liquid form are less satiating (Pan & Hu, 2011).

<sup>2</sup> NCDs are responsible for 71% of global deaths, with dietary factors accounting for an estimated 40% of this burden (WHO, 2022).

<sup>3</sup> In the specific case of SSBs, pass-through to consumer prices (i.e., the extent to which SSB taxes are reflected in consumer prices) is usually substantial. A meta-analysis conducted by Andreyeva et al. (2022) estimated an average pass-through of about 82%, meaning that, for instance, a hypothetical 10% SSB tax would increase retail prices by roughly 8%.

several NCDs and can generate negative externalities, most notably increased healthcare costs, that are ultimately borne by taxpayers, taxation is expected to improve social welfare by reducing demand (Bonnet & Réquillart, 2013; Griffith et al., 2020). This is achieved by internalizing the health-related costs of sugar consumption into the price paid by consumers (Allcott et al., 2019; Di Novi & Marenzi, 2022; Tiboldo et al., 2024). In principle, such mechanisms encourage individuals to account for the long-term health consequences of their dietary choices (Dubois, et al., 2020; Andreyeva et al., 2022).

The effectiveness of SSB taxes in driving manufacturer reformulation, reducing SSB consumption and, ultimately, lowering total sugar intake depends on the combined responses of producers and consumers, and remains a topic of debate. If the levy is fully absorbed by producers and does not translate into higher retail prices, no consumer response is expected, and the public health impact relies entirely on successful reformulation. Conversely, if taxes are passed through to retail prices, consumer behaviour can be shaped by two main factors: (i) the price elasticity of SSBs, which determines how much purchases adjust in response to tax-induced price increases,<sup>4</sup> and (ii) substitution effects, whereby consumers may replace taxed beverages with other untaxed high-calorie foods (e.g., sweets and snacks) or lower-cost SSB alternatives (i.e., brand switching), rather than reducing total sugar intake (Finkelstein et al., 2013; Léger & Powell, 2021).<sup>5</sup> If substitution only involves foods or drinks with similar calorie content, the overall reduction in sugar intake is negligible, making the net public health benefit of the tax minimal. Other factors can play a key role in shaping both industry and consumer responses, such as the tax design (flat tax vs. tiered taxes)<sup>6</sup>, co-interventions (e.g. public awareness campaigns on the adverse health effects associated with high sugar consumption)<sup>7</sup>, and contextual factors (e.g., the strength of industry advertising campaigns, exposure to marketing, and positive attitudes toward soft drinks may influence consumption patterns, making demand less sensitive to price changes).

Previous literature has focused predominantly on demand-side responses to SSB taxation. Most empirical evidence evaluates consumption outcomes using at-home purchase data, while out-of-home purchases have received considerably less attention (see, among others, Fletcher et al., 2010; Fletcher

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<sup>4</sup> Evidence from multiple studies suggests that sugar-sweetened beverage (SSB) taxes are less effective among regular SSB consumers, individuals with lower educational attainment, and socioeconomically disadvantaged populations (see for instance Dubois et al., 2020).

<sup>5</sup> For example, Fletcher et al. (2010), in their analysis, found that increases in soda excise tax rates were associated with reductions in soda consumption among children; however, they did not observe any effect on total caloric intake, as children tended to substitute soda with other untaxed high-calorie beverages.

<sup>6</sup> According to the WHO (2024) report, for instance, tiered taxes, which are levied at higher rates on products containing more sugar, seem to incentivize manufacturers more than flat taxes to reduce the sugar content of SSBs and encourage consumers to reduce their consumption.

<sup>7</sup> Evidence suggests that consumers may lack full information about the harmful effects of SSB consumption. Educational campaigns and disclosure requirements can directly address this gap, potentially reducing SSB intake.

et al., 2013; Dubois, et al., 2020; Kurz & König, 2021). This distinction is important because consumption patterns can differ between settings and may be influenced by factors beyond price (Jensen & Smed, 2018). The hospitality sector often functions as a social setting, where consumers are less price-sensitive and focus more on the overall experience than on the cost of individual beverages, which are typically much higher than for the same products consumed at home.<sup>8</sup> Evidence on consumer substitution patterns is also limited (e.g. Finkelstein et al., 2013), and only a small number of studies explore supply-side implications (e.g. Allais et al., 2023). Yet, taxation alters manufacturers' price structures and may prompt responses such as product reformulation or innovation (Cawley & Frisvold, 2023).

The objectives of this paper are therefore threefold. First, it examines the effect of SSB taxes on sales volumes (annual per capita litres), distinguishing between off-trade channels (retail sales for home consumption) and on-trade channels (sales in bars, restaurants, and cafés). To address this objective, we use Euromonitor International data on soft drink volumes from 2004 to 2019 for six European countries that introduced SSB taxes during this period: Belgium, France, Hungary, Ireland, Portugal, and the United Kingdom (Euromonitor International, 2019; 2024). We also test for potential substitution effects (i.e., cross-price impacts), whereby consumers reduce SSB intake but increase consumption of other untaxed sugary beverages (Zen et al., 2014). To do so, we analyse 100% fruit juice sales in countries where SSB taxes were effective. The category of 100% juices is not subject taxation, by definition, as it does not contain added sugars. Second, the paper investigates how producers respond to SSB taxes through product reformulation and innovation. Using data from the Mintel Global New Products Database for the same six countries, we focus on new or relaunched soft drinks introduced between 2010 and 2019. For each year, we calculate the average sugar content (grams) of these products as an indicator of manufacturers' reformulation behaviour (Mintel Global New Products Database, 2025). Third, as a robustness check, we consider Denmark as a "reverse test" since it is the only country to have implemented an SSB tax significantly earlier than others and later repealed it in 2014.

To estimate causal effects, we apply a synthetic control approach, constructing a weighted combination of European countries without SSB taxes to serve as a control group. This method closely matches pre-treatment trends of the treated unit, allowing us to create a credible counterfactual

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<sup>8</sup> There is a substantial difference in the mark-ups applied across these channels, with higher mark-ups in the on trade reflecting additional costs such as staff service time and amenities.

scenario and mitigate unobserved heterogeneity (Abadie et al., 2010; Kurz & König, 2021; Rieger et al., 2017).

Results show that, the effects of taxation, varied by country. In Portugal, the tax was followed by consistent reductions in off-trade sales. In France, the effect of the 2012 flat-rate tax appeared with a delay, and off-trade consumption started to decrease several years later, possibly reflecting cumulative price effects, or anticipatory behaviour ahead of the 2018 reform. The 2018 shift to a progressive design (where the tax rate increases with the sugar content of the beverage) was associated with moderate declines across both on- and off-trade channels. The UK experienced short-term but statistically significant reductions on off-trade consumption, while Belgium, Hungary, and Ireland showed no significant sales effects. Denmark provides an interesting “natural experiment” in the opposite direction: whereas several European countries have introduced or are planning to introduce excise taxes on soft drinks, Denmark abolished its tax in 2014. Following this repeal, overall consumption of SSBs increased, driven primarily by sales in the on-trade sector. Importantly, no substantial evidence of substitution toward untaxed sugary beverages was found in countries where the SSB tax proved effective in reducing overall SSB consumption. On the supply side, the sugar content of newly launched or reformulated SSBs declined in all countries between 2010 and 2019, with notable increases in reformulation activity in Belgium, France, Hungary, the UK, and Ireland, particularly in the latter two countries following tax announcements. The abolition of the tax in Denmark did not reverse product reformulation.

Overall, our findings are robust to a range of alternative specifications. The Root Mean Squared Prediction Error (RMSPE) from the synthetic control method remains consistently low, indicating a satisfactory pre-intervention fit between treated countries and their corresponding synthetic controls. The results are consistent with tiered, progressive tax structures being relatively more effective in reducing demand and encouraging product reformulation.

The rest of the paper is organized as follows. Section 2 describes the data and variables. Section 3 outlines the empirical strategy and estimation method. Section 4 presents the results, followed by a discussion in Section 5. Section 6 provides the conclusions of this study.

## **2. Data and Variables**

To assess the impact of SSB taxes on sales volumes, distinguishing between off-trade channels (retail) and on-trade channels (hospitality), we draw on SSB sales data from Euromonitor International

covering the period 2004-2019. Euromonitor, a private market research company, collects data from multiple primary and secondary sources, including store audits, company interviews, publicly available statistics, and corporate reports. The dataset spans all EU Member States except Malta and Luxembourg and classifies SSBs into 10 main categories and 57 subcategories, allowing for a detailed examination of beverage types. Our key outcome variable is the total volume of SSBs sold (annual per capita litres), distinguished into off-trade and on-trade sales. The SSB category includes carbonates (the most widely consumed SSB type), juices, concentrates, Ready-to-Drink (RTD) coffee and tea, and sports and energy drinks. We combined the latest Euromonitor edition (2009-2024) with the previous edition (2004-2008) to create a dataset spanning between 2004 and 2019. We excluded data beyond 2019 because the COVID-19 pandemic likely affected soft drink sales in 2020 and may have influenced subsequent sales patterns, particularly in on-trade channels. Our analysis focuses specifically on two SSB categories: carbonated drinks and 100% fruit juices. For carbonates, we considered only regular cola sales to ensure comparability across the two data editions, as non-cola carbonates in the older dataset were not distinguished between regular and reduced-sugar variants. However, artificially sweetened carbonates, which contain minimal sugar, are often not subject to taxation in many countries (see Subsection 3.3).<sup>9</sup> We also analysed 100% fruit juices, which are not taxed because they contain no added sugars, to investigate potential consumer substitution effects.<sup>10</sup>

To examine manufacturers' reformulation strategies, we relied on the Mintel Global New Products Database (GNPD), managed by Mintel, an international company that has provided an extensive food and beverage database since 1972. The database indexes all food and beverage products launched (i.e., newly introduced products or re-launches of existing ones) across 86 countries, with comprehensive coverage of the European market since 1996. Given limitations in data availability prior to 2010, with substantial missing information for variables of interest that may affect data reliability, earlier data were not included in the analysis. We therefore relied on data on new (or rebranded) SSBs launched between 2010 and 2019.<sup>11</sup> For each year, we calculated the average sugar

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<sup>9</sup>Artificially sweetened carbonated beverages are drinks containing artificial sweeteners, such as aspartame and acesulfame-K, as well as naturally derived sweeteners like monk fruit and stevia. They provide few to no calories.

<sup>10</sup>Retail sales volume of regular colas and fruit juices, a non-durable goods, are used as a proxy for consumption, since purchases are expected to closely track consumption. Although minor discrepancies may arise due to temporary stockpiling or inventories, sales data are generally considered a reliable indicator of consumer behavior.

<sup>11</sup> The Mintel Global New Products Database (GNPD) classifies product launches based on manufacturer-reported categories. "New products" refer to items introduced to the market for the first time, whereas "rebranded" (or "relaunch") products capture items reintroduced with modifications. These modifications may include packaging or labeling changes, marketing repositioning, and, in some cases, adjustments to product formulation. While the "rebranded" category may encompass both cosmetic and substantive changes, it is widely used in the literature as a proxy for product renewal and firm-side responses. In our analysis, we focus on observed changes in nutritional content within this group, which provide a consistent measure of product-level adjustments over time.

content (grams per 100 ml) of these beverages. The soft drink categories included carbonated soft drinks, flavoured water, RTD coffee and tea, and juice drinks.

### 3. Empirical Strategy

#### 3.1 The Synthetic Control Approach

To estimate the effect of SSB taxes on SSBs sales and manufacturers' reformulation, we use a synthetic control approach (Abadie et al., 2015; Abadie et al., 2010; Abadie & Gardeazabal, 2003) which is employed in health economics literature to evaluate the effects of nation-wide policies and reforms (Kurz & König, 2021; Rieger, et al., 2017). This method compares the outcome of a treated country (one that introduced an SSB tax) with a synthetic control, constructed as a weighted average of countries from the "donor pool" that have not implemented such a tax. The effectiveness of this approach relies on creating a suitable synthetic control. In what follows, we briefly present the functioning of the synthetic control method and the determination of optimal weights, using the theoretical framework of Pinotti (2015).

Let  $y$  denote one of the following outcomes: (i) the sales volume of regular colas, used as a proxy for consumer demand for SSBs; (ii) the sales volume of 100% fruit juice, used as a proxy for substitution toward untaxed sugary beverages; or (iii) the average sugar content of SSBs (grams per 100 ml), used to capture manufacturers' reformulation behavior. All outcomes may be influenced by the introduction of an SSB tax. In particular, the sales volume of regular colas, 100% fruit juice, or the average sugar content of newly launched or relaunched products SSBs in a given country during year  $t$  is denoted as  $y_t^1$  if the country has implemented a sugar tax, and as  $y_t^0$  otherwise.

$$y_t = \tau_t y_t^1 + (1 - \tau_t) y_t^0 \quad (1)$$

where  $\tau_t$  is an indicator for the implementation of a SSB tax in such country  $\tau_t = 1$  if the tax is implemented and  $\tau_t = 0$  if it is not.

The identification problem concerns estimating the treatment effect of the tax i.e., the effect of the tax on regular cola sales, 100% fruit juice, or the average sugar content of SSBs in each country, denoted by  $\beta_t$ :

$$\beta_t = y_t^1 - y_t^0 \quad (2)$$

It depends on the potential outcomes in both states, even though only one state is observed. Specifically, we cannot observe how the outcome of interest would have evolved for the affected unit in the absence of the intervention. The synthetic control method constructs a “synthetic” version of each treated country by taking a weighted average of countries that were never exposed to the tax. This synthetic country serves as a counterfactual benchmark against which the outcomes of the country that implemented the tax can be compared:

$$\hat{\beta}_t = y_t - \sum_{i \in I} w_i y_{it} \quad (3)$$

where  $w_i$  ( $i = 1, \dots, I$ ) represents the weight assigned to each country  $i$  in the control group  $I$  that contributes to the synthetic control.

$$\hat{\beta}_t = y_t^1 - \sum_{i \in I} w_i y_{it}^0 = \beta_t + (y_t^0 - \sum_{i \in I} w_i y_{it}^0), \forall t > T \quad (4)$$

The accuracy of  $\hat{\beta}_t$  as an estimate of  $\beta_t$  depends on the content of the parentheses in equation (4) specifically on the difference between  $y_t^0$  and  $\sum_{i \in I} w_i y_{it}^0$  which should be minimized. A natural approach would be to minimize the difference between the treated country, subject to the SSB tax, and the control countries during the period when neither group was exposed to the tax (i.e. before the period  $T$ ).

Following Abadie & Gardeazabal (2003), we adopt a two-step procedure. First, let  $\mathbf{x}$  be a ( $K \times 1$ ) vector of pre-treatment characteristics for the treated country, and  $X_0$  ( $K \times I$ ) matrix containing the same variables for the  $I$  possible control countries. Let  $V$  be a positive definite diagonal matrix. Conditional on  $V$  the vector of weights,  $W * (V)$  must solve the following

$$\min(X_1 - X_0 W)' V (X_1 - X_0 W) \quad (5)$$

subject to  $w_i \geq 0$  and  $\sum_{i \in I} w_i = 1 = I, \forall i = 1 \dots I$ . The goal is to minimize differences in predictor values and regular cola sales volumes/ 100% fruit juice / average sugar content of SSBs between each treated country and its synthetic control during the pre-treatment period, measured by the root mean squared prediction error (RMSPE) of outcomes over a specified period prior to the tax implementation:

$$\sqrt{\frac{1}{T^0} \sum_{t \leq T^0} (y_t - \sum_{i \in I} w_i^* y_{it})^2}, \forall T^0 \leq T \quad (6)$$

The computed weights are then applied to the post-treatment regular cola sales volumes/ 100% fruit juice / average sugar content of SSBs of control units to simulate the sales/reformulation trajectory of the treated country in case the SSB tax had not been implemented. If the synthetic control and treated units are balanced, this approach allows for estimating the treatment effect while accounting for unobserved factors, thereby reducing omitted variable bias.

### **3.2 Identification of Treated and Control Units**

Starting from the demand side, using Euromonitor data, we applied the synthetic control method to six European countries that implemented an SSB tax during 2004-2019: Belgium, France, Hungary, Ireland, Portugal, and the United Kingdom. We excluded Finland and Latvia because their SSB taxes were first introduced in May 2001 and January 2004, respectively, although Finland's tax was revised in 2011 and Latvia's in 2016 and 2022. We also excluded Croatia, Poland, and Spain, which introduced SSB taxes after our observation period (Croatia in 2020, Poland and Spain in 2021). The Spanish region of Catalonia introduced an SSB tax in 2017, but it was not included due to the lack of subnational data. Denmark was excluded as well, since its soft drink tax, initially introduced in the early 1930s, was repealed in 2014. As control units, we selected fourteen European countries from the Euromonitor database that neither introduced an SSB tax during the observation period nor shortly after (to avoid potential anticipatory effects on sales): Austria, Bulgaria, the Czech Republic, Estonia, Germany, Greece, Italy, Lithuania, the Netherlands, Poland, Romania, Slovakia, Slovenia, and Sweden.

On the supply side, using Mintel data to analyse average sugar content as a proxy for producers' reformulation strategies, the control group includes Austria, the Czech Republic, Germany, Greece, Italy, Norway, Poland, and Sweden. Due to the smaller number of countries available in the Mintel dataset, the control group is correspondingly smaller.

In what follows, we present the main characteristics of the excise taxes on SSBs implemented in the treated countries. The information is primarily drawn from the *Global SSB Tax Database* developed by the World Bank, which provides comprehensive data on all verified SSB taxes worldwide (World Bank Group, 2023). Further details can be found in Hattersley & Mandeville (2023) and in European Commission (2025).

## ***Belgium***

The Belgian government introduced an SSB tax for the first time in December 2009, according to the “Loi relative au régime d'accise des boissons non alcoolisées et du café” (Law on Excise Duty on Non-Alcoholic Beverages and Coffee). The tax was subsequently revised and increased in December 2015, with the revision taking effect in January 2016 (see also Thow et al., 2022). This tax applies to all soft drinks, including non-alcoholic beverages, mineral waters, and carbonated waters containing added sugars, sweeteners, or flavourings. An excise duty of €0.41 per litre is imposed on soft drinks with added sugars or sweeteners, as well as on liquid concentrates. For powdered, granulated, or other solid concentrate forms, the tax is set at €0.68 per kilogram.

## ***France***

France was one of the first European countries to implement a SSB tax in 2012. Initially, the tax applied to both sugar-sweetened and artificially sweetened drinks at a flat rate of €0.076 per litre. In 2018, the law was revised to introduce a progressive tax based on sugar content. The tax ranges from €0.03 per litre for drinks containing up to 1g of sugar per 100 ml, to €0.24 per litre for those with 15g of sugar per litre. For beverages with more than 15g of sugar per litre, an additional charge of €0.0205 per kilogram of added sugar is imposed.

## ***Hungary***

Hungary introduced a tax (i.e. the Public Health Product Tax – NETA) on unhealthy foods and beverages in 2011, targeting products associated with proven health risks, including those containing high levels of sugar, salt and fat (UNICEF, 2019)

The tax was announced in February 2011, finalized in June, and came into effect in September of the same year. It applies to soft drinks containing more than 8g of sugar per 100 ml. Exemptions include fruit and vegetable juices, nectars with at least 50% fruit or vegetable content.

## ***Ireland***

The Sugar-Sweetened Drinks Tax (SSDT), also known as the Sugar-Sweetened Beverage Tax (SSBT) or simply the "sugar tax," was announced in 2016 and implemented in May 2018, with a slight delay to align with the introduction of a similar tax in the UK (also to address the concerns of

Irish retailers in the border region, who feared that this tax might drive potential customers north, into Northern Ireland (Houghton et al., 2024). The SSDT was amended in January 2019. Currently, the tax applies to non-alcoholic, water-based drinks and fruit-based drinks with added sugar content of 5g or more per 100 ml. It also includes plant protein drinks and milk fat-containing beverages with less than 119 mg of calcium per 100 ml, as well as concentrates intended for drink preparation. The SSDT is structured as a tiered excise duty with three rates based on sugar content. Beverages with less than 5g of sugar per 100 ml are exempt from the tax. For beverages containing between 5g and 8g of sugar per 100 ml, the tax is € 0.16 per litre. For beverages with 8g or more of sugar per 100 ml, the tax rises to € 0.24 per litre.

### ***Portugal***

In Portugal, the sugar tax was implemented in February 2017 and applies to mineral, flavoured, and carbonated waters containing added sugars or sweeteners, as well as concentrates. The tax was first introduced with two tiers: beverages containing less than 8 grams of sugar per 100 ml were taxed at €0.08 per litre, while those with 8 grams or more per 100 ml were taxed at €0.16 per litre. In 2018, both rates were slightly increased. Juices, nectars, and drinks based on milk, soy, or rice were excluded. In 2019, the system was revised to better differentiate drinks according to their sugar content. The lower tier was divided into three sub-tiers, with reduced rates, while the tax on the sugariest drinks was increased. Since then, the current rates are as follows: drinks with less than 2.5 grams of sugar per 100 ml are taxed at €0.01 per litre; those with 2.5 to 4.9 grams per 100 ml at €0.06; drinks with 5 to 7.9 grams per 100 ml at €0.08; and beverages with 8 grams or more per 100ml at €0.20 (see also Gonçalves et al., 2024).

### ***United Kingdom***

The Soft Drinks Industry Levy (SDIL), commonly referred to as the "sugar tax", was announced in March 2016 and implemented in April 2018.<sup>12</sup> The SDIL applies to prepackaged soft drinks containing at least 5g of total sugars per 100 ml, with added sugar defined as monosaccharides, disaccharides, or any sugar-containing ingredient, excluding fruit juice, vegetable juice, and milk. The levy is structured as a two-tiered tax, charging producers based on the sugar content of their drinks. Beverages with more than 8g of sugar per 100 ml are taxed at £0.24 per litre, while those

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<sup>12</sup>The SDIL was intentionally announced in 2016, two years before its implementation in 2018, to give manufacturers time to reformulate SSBs by reducing the sugar content of their products (Allais et al., 2023).

containing between 5g and 8g of sugar per 100 ml are taxed at £0.18 per litre. Exemptions apply to milk-based drinks, pure fruit juices, powder-based drinks, and beverages with an alcohol content greater than 1.2%.

### 3.3. Synthetic Control Model Implementation

To evaluate the effects of SSB taxation on consumer demand and substitution behaviour, we conduct separate analyses for off-trade and on-trade channels. The optimal weighting scheme and time window used to minimize equations (5) and (6) are selected based on pre-tax sales volumes of regular colas and 100% fruit juice. Each specification was estimated both with and without a set of covariates, including log GDP, the population shares of children and adolescents, mean temperature.<sup>13</sup>

To assess the impact of SSB taxation on product reformulation, the optimal weights and time window minimizing equations (5) and (6) were determined using pre-tax data on the average sugar content (grams per 100 ml) of newly launched or reformulated SSBs.

All calculations were performed in STATA 18.0 using both the `synth` and the `synth_runner` command (see Galiani & Quistorff, 2017). The `synth_runner` command relies on a permutation method that repeatedly assigns treatment status to each control unit as a placebo test, while excluding the actual treated unit from being used in the construction of synthetic controls for the placebo units. The underlying intuition is that, if SSB taxes have a detectable effect, the treated country should deviate more from its synthetic control than non-treated countries (i.e., placebos) deviate from theirs. In other words, to formally evaluate whether SSB taxes affected beverage sales or whether manufacturers engaged in reformulation of newly launched or rebranded soft drinks during the treatment period, the `synth_runner` calculates two sets of p-values. First, it compares each treated country with its synthetic control during the treatment period by computing the post-treatment root mean squared prediction error (RMSPE). It then calculates the analogous post-treatment RMSPEs for all control countries (placebos) and ranks them. The proportion of placebo post-treatment RMSPEs that are greater than or equal to the treated unit's post-treatment RMSPE serves as the p-value (`pvals`).

However, this p-value can be influenced by the overall pre-treatment fit, potentially leading to misleading inferences. The `synth_runner` command offers an alternative, in which p-values are calculated as the ratio of post- to pre-treatment RMSPEs rather than from the post-treatment RMSPE

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<sup>13</sup> For the sake of brevity, the paper reports only the results based on pre-tax sales volumes. Estimates including covariates are available from the authors.

alone, thereby adjusting for the quality of pre-treatment matches. This measure (`pvals_std`) captures the relative deterioration in fit during the treatment period.<sup>14</sup>

In our analysis, we focus on `pvals_std`, considering coefficients significant when it reaches the standard thresholds for statistical significance.

## 4. Results

In this section, we examine the effect of the SSB tax on consumption, measured by regular colas volume sales; the potential substitution effect among consumers; the reformulation responses by producers. The section concludes with a separate subsection on the case of Denmark. All models were estimated under different specifications, and across all estimations, the RMSPE remains low, indicating a high-quality match between the treated countries and their respective synthetic controls.

### 4.1. Total Sales of Regular Cola Carbonates

Figure 1, based on Euromonitor data, shows a clear declining trend in the per capita volume of regular cola carbonates sold (litres per year) across all six countries that introduced an SSB tax between 2004 and 2019, with sales distinguished between off-trade and on-trade channels. Comparing the first and last years of observation, Portugal recorded the largest decrease, with off-trade sales falling by 35.8% and on-trade sales by 41.3%. Ireland experienced the second-largest decline, with reductions of 31.2% in off-trade and 36.0% in on-trade sales. In France, the decline was more moderate, around 21% in off-trade and 9% in on-trade sales. The UK was the only country where the decrease in on-trade sales, equal to 20.9%, exceeded that in off-trade sales, which fell by 15.6%. In Belgium, declines were of similar magnitude, with off-trade sales decreasing by 14.5% and on-trade sales by 13.6%. Hungary showed the smallest reduction in off-trade sales, down by 10.2%, but a more pronounced contraction in on-trade sales, down by 19.7%.

[Figure 1 about here]

Among the control countries, while Western Europe recorded a decline in total regular carbonated cola sales, particularly within the off-trade segment, this downward trend was not uniform across the

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<sup>14</sup> Minor discrepancies between treated and synthetic units in the pre-treatment period are expected and do not invalidate inference, provided that the relative deterioration in fit during the treatment period is large compared to placebo units.

continent. Total SSB sales increased over the same period in Bulgaria, the Czech Republic, Poland, Romania, Estonia, and Lithuania, while Slovenia displayed relatively stable consumption levels. A similar pattern was observed in the on-trade segment, with rising sales in the same countries, except for Slovenia, which remained stable.

Tables 1A and 1B present the estimated treatment effects of the SSB tax on the total volume of regular cola carbonates sold, using the synthetic control method, disaggregated by off-trade and on-trade channels for each treated country. These results are further shown in Figure 2 (panels a–f).

[Table 1A about here]

[Table 1B about here]

[Figure 2 about here]

The estimated coefficients from the synthetic control method indicate that Belgium and Ireland did not experience any statistically significant effects on either off-trade or on-trade sales following the introduction of the SSB tax, suggesting that no meaningful differences exist between each treated country and its respective synthetic control. For Belgium, the analysis was conducted twice: once for the 2009 introduction and once for the 2016 revision, considering both off-trade and on-trade consumption. In Hungary, where the tax was introduced at the end of 2011, weakly significant negative effects (at 90%) on on-trade sales are observed from 2011 through 2018, with estimated coefficients remaining small in magnitude (ranging from -0.30 to -0.06 litres per capita per year). In 2019, the last year of observation, a small positive coefficient is observed, indicating a slight increase in consumption. As previously noted, the overall trend in sales across all countries has been declining in both the on-trade and off-trade market segments.

France introduced an SSB tax in 2012 as a flat-rate levy. In 2018, this flat tax was replaced by a progressive tax, with the rate proportional to the amount of sugar added to beverages (see Subsection 3.2 for details). Accordingly, we repeated the analysis for France for both years: 2012 and 2018, considering both off-trade and on-trade consumption. When the policy cut-off was set at 2012, the estimated coefficients for off-trade consumption were not statistically significant until 2016, but became significant in 2017, 2018, and 2019 (-1.98, -2.97, and -2.91 litres per capita, respectively). Relative to the pre-intervention consumption level in 2011 (19.2 litres per capita), these correspond to reductions of approximately 10.3%, 15.5%, and 15.2%, respectively. The flat tax introduced in 2012 did not produce an immediate decline in off-trade regular cola carbonate sales, but consumption

started to decrease several years later, possibly reflecting cumulative price effects, or anticipatory behaviour ahead of the 2018 reform. When the intervention year is shifted to 2018, the estimated coefficients for off-trade consumption are smaller (-1.32 and -1.13 litres per capita for 2018 and 2019, respectively), corresponding to declines of approximately 8.8% and 7.5% relative to the 2017 pre-reform level of 15 litres per capita. Overall, these results indicate a gradual decline in off-trade regular cola sales, initially triggered by the 2012 tax and subsequently reinforced by the 2018 reform. The 2018 shift to a progressive design was associated with moderate declines in the on-trade channel too, with a coefficient of -0.25, corresponding to a decline of approximately 5.3% relative to the 2017 pre-reform level of 4.7 litres per capita.

For Portugal, synthetic control estimates indicate that the tax was associated with reductions in annual per capita off-trade sales of regular colas of 1.77 litres in 2017 (-18.8% relative to the 23 litres per capita recorded in the pre-tax year), 2.05 litres in 2018 (-21.8%), and 2.35 litres in 2019 (-25.0%) relative to the counterfactual. This analysis was performed only once for Portugal, as the SSB tax changed only slightly in 2018, and 2019 (the year in which the system was revised to better differentiate drinks according to their sugar content - see Subsection 3.2) represents the last observation year in our study. Coefficients for on-trade sales were negative but not statistically significant.

Finally, in the UK, where the SSB tax was announced in 2016 and implemented in 2018, we observe a negative and statistically significant effect on off-trade sales for the first year of the implementation. In that year, the estimated coefficient was -0.93 litres for off-trade sales, corresponding to a reduction of about 5.7% relative to the pre-tax level. No significant effect was found for on-trade sales.

#### **4.2 Consumers' Substitution Effect**

In this subsection, we test for the presence of a substitution effect whereby consumers, in response to the tax, reduce their regular colas consumption but increase their intake of other untaxed sugary beverages offsetting the intended dietary and health impacts of such policies. To this end, we replicated the analysis using sales volumes of 100% fruit juice in those countries where the SSB tax proved effective according to our results, namely France, Portugal, and the UK. The category of 100% juices is not subject taxation, by definition, as it does not contain added sugars. However, 100% juices contain considerable amounts of free sugars and thus contribute significantly to total energy intake.

The results of the synthetic control model are presented in Tables 2A and 2B and Figure 4 (panels a-c).

[Table 2A about here]

[Table 2B about here]

[Figure 3 about here]

Overall, our results provide no evidence of substitution toward untaxed beverages, except for slight to moderate increases in off-trade 100% fruit juice sales following the implementation of the SSB tax in France in 2012 and 2013, which subsequently diminished, consistent with Bonnet & Réquillart (2013).

It is also plausible that the market for sugary drinks is so diverse and heterogeneous that consumers have access to a wide range of sweetened beverages. In this context, they might not reduce their overall consumption but rather adjust their choices, shifting toward cheaper yet similar sugar-sweetened beverages (e.g. replacing a branded cola with a lesser-known alternative). However, this remains a hypothesis, as the available data do not allow us to verify whether such substitution occurs.

### **4.3 Producers' Reformulation**

The descriptive trends shown in Figure 4 indicated that, between 2010 and 2019, the average sugar content (grams per 100 ml) of newly launched or reformulated SSBs declined across all six treated countries included in the analysis. Comparing the first and last years of observation, the most pronounced reduction was observed in Belgium (-33%), the first of the treated countries in our sample to implement an SSB tax, followed by the UK (-29%) and Portugal (-22%). More moderate declines occurred in France (-16%) and Ireland (-15%), while Hungary (-8%) stands out as the only country without a consistent trend, showing an initial reduction, followed by an increase and a subsequent decrease. All control countries included in this analysis, namely Austria, the Czech Republic, Germany, Greece, Italy, Norway, Poland, and Sweden, exhibited a decline in the average sugar content, except for Germany and Italy.

[Figure 4 about here]

The results of the synthetic control model are shown in Table 2 and in Figure 5 (panels a-f).

[Table 3 about here]

[Figure 5 about here]

Belgium introduced an SSB tax in 2009, as described in Subsection 3.2. However, since the observation period in the Mintel data begins in 2010, our analysis focuses solely on the effect of product reformulation following the 2016 policy revision. The reform did not alter the tax structure, which remained a fixed amount. The results indicated that the policy was effective: from 2017 onwards, the sugar content of newly launched or rebranded products (grams per 100 ml) declined progressively by 1.27 g in 2017, 2.07 g in 2018, and 2.29 g in 2019.

For France, we replicated the empirical exercise three times: (i) assessing reformulation effects in 2012 (the year of policy implementation) and using as the dependent variable the sugar content (grams per 100 ml) of newly introduced or rebranded SSBs; (ii) evaluating policy effects after the tax design was revised from a flat-rate to a proportional structure in 2018; and (iii) estimating its impact on the share of new beverages exceeding the 1 g sugar threshold in 2018. Our results indicated a significant policy effect starting in 2018, with the sugar content of newly launched or relaunched products declining by approximately 0.61 g/100 ml in 2018 and 0.76 g/100 ml in 2019. However, this effect did not translate into a significant reduction in the share of new or relaunched products with sugar levels below 1 g/100 ml.

As previously discussed, Hungary introduced a tax on unhealthy foods and beverages in 2011 (see Subsection 3.2). The measure applies to soft drinks containing more than 8 g of sugar per 100 ml. Accordingly, we replicated the empirical exercise in two ways: (i) assessing reformulation effects in 2011, using as the dependent variable the sugar content (grams per 100 ml) of newly introduced or rebranded SSBs; and (ii) estimating the impact of the tax on the share of new beverages exceeding the 8 g sugar threshold. The results were not statistically significant when considering the average sugar content of newly launched SSBs, suggesting that no substantial reformulation occurred on the producers' side. However, when using the 8 g sugar threshold, the results were statistically significant and revealed clear short-term effects. In the first year (2011), the share of new beverages exceeding 8 g of sugar declined by 19%, followed by a 26% reduction in 2012. The effect was less consistent in subsequent years: in 2013 and 2014, the coefficients were negative but not statistically significant, corresponding to reductions of 18% and 11%, respectively, while in 2015 the decline, statistically significant, was as much as 15%. These findings, however, should be interpreted with caution, as the pre-intervention period is very short: we can rely on only one year of observations before the introduction of the tax.

In Ireland, the SSB tax was announced in 2016 and implemented in 2018, applying to soft drinks containing more than 5 g of sugar per 100 ml. We conducted four analytical exercises: (i) assessing

reformulation effects in 2018, the year of policy implementation, using the sugar content (grams per 100 ml) of new or relaunched soft drinks as the dependent variable; (ii) evaluating policy effects based on the year of announcement (2016) rather than implementation; (iii) examining the share of new beverages exceeding the 5 g sugar threshold in 2018; (iv) performing the same analysis for 2016, the year the policy was announced. When the policy cut-off is set at 2018, coinciding with the official implementation, we observe a statistically significant reduction in sugar content in newly/relaunched products in 2018, with a coefficient of -1.88 g/100 ml. No statistically significant post-treatment effect was observed in 2019. When the treatment was defined as beginning in 2016, a gradual decline in average sugar content was observed both in 2017 and 2018, with the largest reduction in 2018 (-2.318 g/100 ml). In 2019, the reduction diminished to -0.969 g/100 ml, indicating that the effect did not persist at its 2018 peak, although sugar content remains slightly lower than in 2017 (-1.45 g/100 ml). The analysis of the share of new beverages exceeding the 5 g sugar threshold reveals a continuous increase from about 6% in 2016, peaking at over 20% by 2018. In 2019, the share returned to a level like that of 2016 (around 5.2%), suggesting that fewer new products exceeded the policy threshold immediately following the announcement.

For Portugal, we tested the reformulation hypothesis by: (i) assessing reformulation effects in 2017 (the year of policy implementation) using as the dependent variable the sugar content (grams per 100 ml) of newly launched or relaunched SSBs; and (ii) evaluating policy effects by estimating its impact on the share of new beverages exceeding the 8 g sugar threshold. Neither exercise yielded statistically significant results.

In the UK, the SSB tax was deliberately announced in 2016, two years prior to its implementation in 2018, to give manufacturers time to reformulate their products by reducing sugar content. The tax applies to pre-packaged soft drinks containing at least 5 g of total sugars per 100 ml (see Subsection 3.2 for details). As in Ireland, we conducted four analytical exercises: (i) assessing reformulation effects in 2018 (the year of policy implementation), with the dependent variable defined as the sugar content (grams per 100 ml) of new or rebranded SSBs; (ii) evaluating policy effects based on the year of announcement rather than implementation; (iii) examining the policy effect specifically, by estimating its impact on the share of new beverages exceeding the 5 g sugar threshold in 2018; and (iv) performing the same analysis for 2016, the year the policy was announced. Like Ireland (whose SSB tax was designed following the UK model), when the policy cut-off was set at 2018, coinciding with the official implementation of the SSB tax, we observed a statistically significant reduction in sugar content in 2018, with a coefficient of -0.91 g/100 ml, and -1.29 g/100 ml in 2019. When the treatment was defined as beginning in 2016, a gradual decline in average sugar content is observed

from 2017 (the year following the announcement) through 2019, ranging from -1.27 g/100 ml to -1.78 g/100 ml. The analysis of the share of new beverages exceeding the 5 g sugar threshold revealed a continuous increase from about 12% in 2017, peaking at over 25% by 2019, again suggesting that fewer new products exceeded the policy threshold immediately following the announcement.

#### **4.4 Denmark: A Reverse Policy Experiment**

In Denmark, the SSB tax was first introduced in the 1930s. Its initial purpose was not health-related, but to increase fiscal revenues. The first major revision of the tax occurred in 2012, when it was reoriented toward public health objectives. On that occasion, in addition to soft drinks, taxes on confectionery, chocolate, ice cream, and tobacco were also increased. The excise duty, which had initially applied to all SSBs, was raised only for beverages containing more than 5 grams of sugar per 100 ml, increasing from 1.08 DKK (approximately €0.14) to 1.58 DKK (approximately €0.21) per litre. In July 2013, however, the taxes were reduced: for beverages with more than 5 grams of added sugar per 100 ml, the rate was lowered to 0.82 DKK (approximately €0.11) per litre, while for those with less than 5 grams, it was reduced to 0.3 DKK (approximately €0.04) per litre. Both taxes were then completely abolished in January 2014 (see also Schmacker & Smed, 2020 for additional details). The abolition was justified on fiscal grounds, as the government sought to limit revenue losses resulting from cross-border trade and the illicit sale of soft drinks.

The Danish case is peculiar: while several European countries have introduced, or are planning to introduce, excise taxes on soft drinks (in Italy, for instance, the introduction of the tax is scheduled for January 2026, although repeatedly postponed), Denmark has instead abolished it. The Danish case offers an interesting “natural experiment”: whereas the introduction of an SSB tax is expected to discourage the consumption of high-sugar beverages, by increasing their retail price and shifting demand toward healthier alternatives, as well as incentivizing manufacturers to reformulate their products by reducing sugar content, a tax abolition could, conversely, lead to increased consumption and weaker reformulation incentives. We therefore tested this hypothesis using data from Euromonitor and Mintel, respectively.

Figure 6 shows that in Denmark, according to the Euromonitor data, off-trade consumption trend of regular cola carbonates (panel a) declined from 31.5 litres per capita in 2004 to 26.6 litres per capita in 2019. The decline was particularly marked until 2012 (21.9 litres), coinciding with the revision of the SSB tax, after which sales increased to 23.8 litres per capita in 2013 following a tax reduction, and further to 26.4 litres per capita in 2014, the year the tax was abolished. Sales trend remained relatively stable thereafter. On-trade consumption trend remained largely stable over the period, with

a slight dip in 2012, followed by increases in 2013 and 2014, ultimately stabilizing at around 7 litres per capita. The trend in the average sugar content (g/100 ml) of newly launched or relaunched SSBs from 2010 to 2019, according to Mintel data, shows a sharp decline from 18.58 in 2010 to around 9-10 g/100 ml in 2011-2012, the year preceding the revision of the SSB tax. In 2012, sugar content shows a slight increase, followed by a gradual decrease to 8.50 g/100 ml in 2013, the year before the tax was repealed. From 2014 onwards, sugar content stabilizes around 8–9 g/100 ml, with minor fluctuations in the subsequent years.

[Figure 6 about here]

The results of the synthetic control model are presented in Table 4 and Figure 7 (panel a, b and c). Significant effects are observed only for per capita regular carbonate sales within the on-trade channel, where a notable increase in consumption occurs following the abolition of the tax, while no significant effect is detected for producers' reformulation. Specifically, compared to the synthetic control, on-trade consumption increased by approximately 1.07 litres per capita in the first post-repeal year (2014), corresponding to about 16% rise relative to 2013. In subsequent years, consumption continued to exceed the synthetic control, reaching roughly 7.9 litres per capita by 2016, with minor fluctuations in 2017 and 2018, before stabilizing at a similar level in 2019. These findings indicate that the abolition of the tax led to a sustained increase in on-trade regular cola consumption relative to the expected counterfactual trend.

[Table 4 about here]

[Figure 7 about here]

In all our empirical analyses, which analyse the effect of SSB taxes on consumption, we distinguished between on-trade and off-trade channels, based on the hypothesis that the effect of an SSB tax may vary depending on whether consumption occurs in restaurants or when beverages are purchased in retail stores for home consumption. Our findings indicate that, in most countries SSB taxes, when effective, tend to reduce off-trade (home) consumption more substantially, as consumers are generally more sensitive to price increases in this market when the tax is passed through. Denmark, however, represents an exception: the abolition of the SSB tax appears to have primarily affected on-trade consumption, with no significant impact on off-trade sales.

This counterintuitive pattern may be explained by differences in tax pass-through rates across distribution channels. The soft drink market is highly concentrated and characterized by a non-linear transmission of taxation. Empirical evidence shows that, in the case of SSB taxes, the tax burden is generally passed on to consumers through price increases and, in some instances, the pass-through

may even exceed the nominal value of the tax itself (Cawley & Frisvold, 2017). In Denmark, a case of over-shifting of excise taxes on soft drinks has been documented in a highly concentrated market, where the three main retail chains account for approximately 90 percent of total sales (Bergman & Hansen, 2019; Schmacker & Smed, 2020). Such over-shifting typically occurs in market segments where demand is less price elastic and may reflect pricing strategies adopted by producers and retailers to maintain overall consumption levels while avoiding declines in more price-sensitive segments (Lauer et al., 2023). When the tax was abolished, price reductions may therefore have been transmitted more directly to on-trade consumers, amplifying the effect on that channel.

An additional factor explaining the asymmetric effects across distribution channels is cross-border shopping. Before the repeal of the SSB tax, a significant share of Danish soft drink consumption occurred in German grocery stores, driven by price differences and easy border access. In 2013, the Ministry of Taxation estimated that cross-border purchases accounted for about 23 percent of total soft drink sales (The Danish Ministry of Taxation, 2014), mostly involving off-trade consumption (goods bought for consumption elsewhere) rather than on-trade consumption, which takes place at bars, restaurants, or cafés (Kluser, 2025). After the tax was abolished, some off-trade demand likely returned to the domestic market, with only a modest increase in volume. In contrast, on-trade consumption, less affected by cross-border shopping, benefited directly from the price reduction, resulting in a genuine sales increase in the hospitality sector.

Overall, total regular cola consumption rose, driven mainly by on-trade sales, confirming that SSB taxation can effectively reduce sugar-sweetened beverage consumption.

Apparently, the abolition of the SSB tax did not lead to a reversal in product reformulation. One possible explanation for the absence of “inverse reformulation” is that producers had already adjusted their product portfolios to align with the preferences of increasingly health-conscious consumers, maintaining relatively low-sugar soft drinks even after the tax repeal. This pattern is illustrated in Figure 6 for Denmark, where the average sugar content steadily declined up to 2013, followed by a slight increase after the abolition of the tax, but remained largely stable thereafter at a relatively low level, consistently below 10 grams per 100 ml.

## **5. Discussion**

This paper investigates the impact of SSB taxes, designed to reduce sugar intake and improve public health by preventing diet-related NCDs, on both consumption and producer behaviour in six European countries: Belgium, France, Hungary, Ireland, Portugal, and the United Kingdom. Our

analysis focuses on four main aspects. First, we examine the effect of SSB taxes on sales volumes, distinguishing between off-trade and on-trade channels, to assess whether they effectively reduce consumption. Second, we test for potential substitution effects, investigating whether consumers reduce SSB intake but increase consumption of other untaxed sugary beverages, such as 100% fruit juice. Third, we analyse manufacturers' responses by studying reformulation and innovation strategies, focussing on the sugar content of newly launched or relaunched soft drinks as a proxy. Fourth, we consider Denmark, which introduced an SSB tax earlier than other European countries and repealed it in 2014, as a "reverse" case to examine whether the removal of the tax led to changes in consumption patterns or product reformulation. Our analysis employs a synthetic control approach to estimate the effects of these taxes, which accounts for time trends that would have occurred in the absence of the tax, thereby minimising bias in policy effect estimates (Cawley & Frisvold, 2023).

Our findings indicate that the effects of SSB taxes varied across countries. Significant reductions in sales were observed in France following the 2018 revision, which changed the tax from a fixed to a tiered structure, and in Portugal. In the United Kingdom, the introduction of the SSB tax led to a significant short-term decline in both on-trade and off-trade sales. By contrast, no statistically significant effects were detected in Belgium, Hungary, or Ireland. There is no evidence of substitution toward 100% fruit juices in countries where SSB taxes effectively reduced consumption, except for a moderate increase in off-trade consumption in France in 2012-2013, which later disappeared.

On the supply side, Mintel data suggest that reformulation was particularly effective in Belgium and accelerated markedly in France following the 2018 progressive tax revision. Similar patterns were observed in the UK and Ireland, particularly from the year of policy announcement.

The Danish case provides important insights into channel-specific and supply-side effects of SSB taxation. The abolition of the tax led to a modest increase in overall SSB sales, primarily in the on-trade sector, highlighting how price changes may impact consumption differently across settings. Off-trade consumption remained largely unaffected, likely due to cross-border shopping and prior consumer adjustments. Notably, the repeal did not reverse product reformulation: manufacturers had already aligned their portfolios with health-conscious preferences, maintaining relatively low sugar levels in new products.

Overall, our findings indicate that fiscal instruments like SSB taxes can influence both consumption and sugar content, and that design is critical for effectiveness. Tiered taxes, applying higher rates to beverages with higher sugar content, appear more effective in reducing soft drink consumption.

Progressive designs with explicit sugar thresholds and early announcements may also incentivise industry reformulation more effectively.

We want to acknowledge some limitations of our study. Euromonitor and Mintel data are not sufficiently granular to allow detailed analyses by age or socio-economic subgroup, so our results reflect aggregate outcomes. Soft drink sales data do not fully capture potential substitution toward lower-cost SSB alternatives within the same category. Regarding reformulation, we observe sugar content only for newly launched beverages, lacking information on existing products.

Despite these limitations, our study has several strengths. Unlike many previous studies that focus exclusively on either demand or supply, we combine both perspectives by using Euromonitor and Mintel data, providing causal estimates of SSB tax effects across European countries. We tested the robustness of our results using multiple specifications, including the Danish “reverse” test and an analysis of 100% fruit juice sales to examine potential substitution effects. Overall, this approach offers a more comprehensive assessment of SSB taxes and their impacts than much of the existing literature.

## **6. Conclusions**

One of the most important objectives of policy instruments such as the SSB tax is to internalize the negative externalities associated with healthcare costs linked to diet-related NCDs and, more broadly, to reduce sugar consumption, ultimately curbing the global rise in obesity rates. However, the extent to which such measures are effective in reducing NCDs burden remains an open question. To date, no studies have established a causal link between the introduction of SSB taxes and measurable reductions in diet-related NCDs prevalence in the countries that have implemented them. Reducing SSB consumption and incentivizing product reformulation represent important steps toward addressing diet-related NCDs. However, a broader and more integrated approach is required, combining fiscal policies with educational and regulatory interventions. Such an approach could include mandatory product reformulation to reduce sugar content, increased availability and promotion of healthy beverages such as water in schools and public settings, restrictions on marketing and advertising of sugary drinks, as well as subsidies for fruits, vegetables, and other healthy options. It is fundamental that SSB taxes are not perceived merely as revenue-raising instruments but as integral components of a comprehensive public health strategy to promote healthier dietary behaviours. The underlying principle should be to make unhealthy options less affordable and less economically attractive through taxation, while simultaneously making healthier alternatives more accessible and appealing by lowering their relative price through subsidies.

Further research on SSB taxation remains crucial to better understand its long-term effects on diet and health outcomes, as well as to explore heterogeneity in producer and consumer responses to inform more effective policy design.

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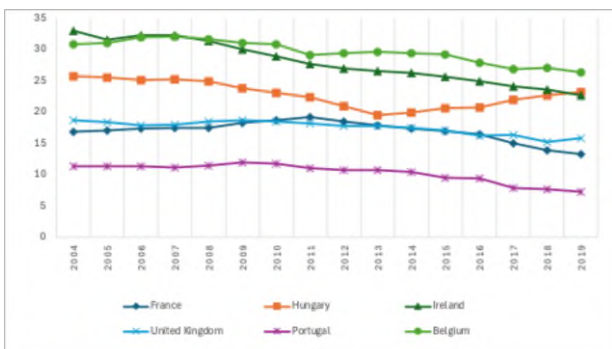
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## FIGURES & TABLES

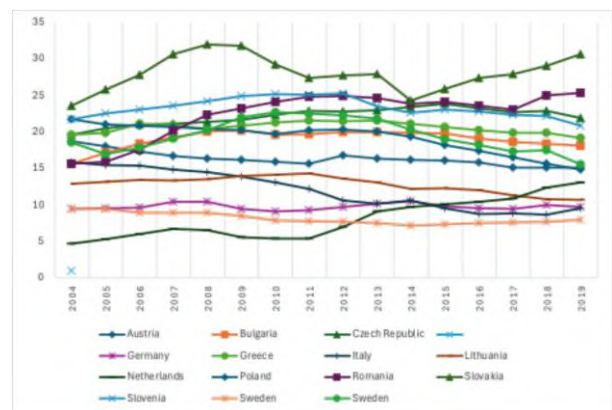
**Figure 1 - Per capita Regular Cola Carbonates sales volumes (litres) in treated vs control countries 2004-2019: off-trade (Panel a) and on-trade (Panel b) \*. Euromonitor data.**

### Panel a

#### Off-trade - treated countries

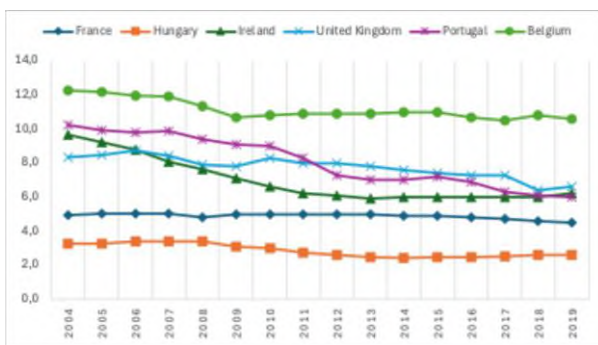


#### Off-trade - control countries

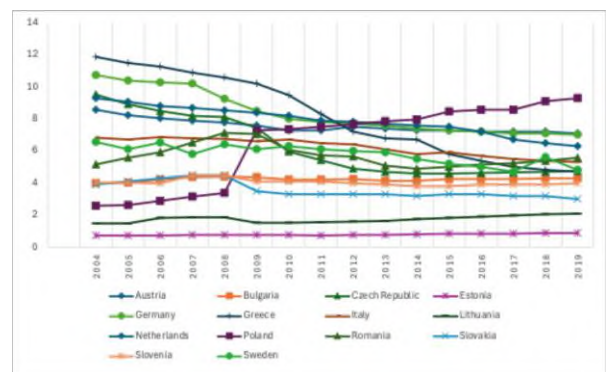


### Panel b

#### On-trade - treated countries

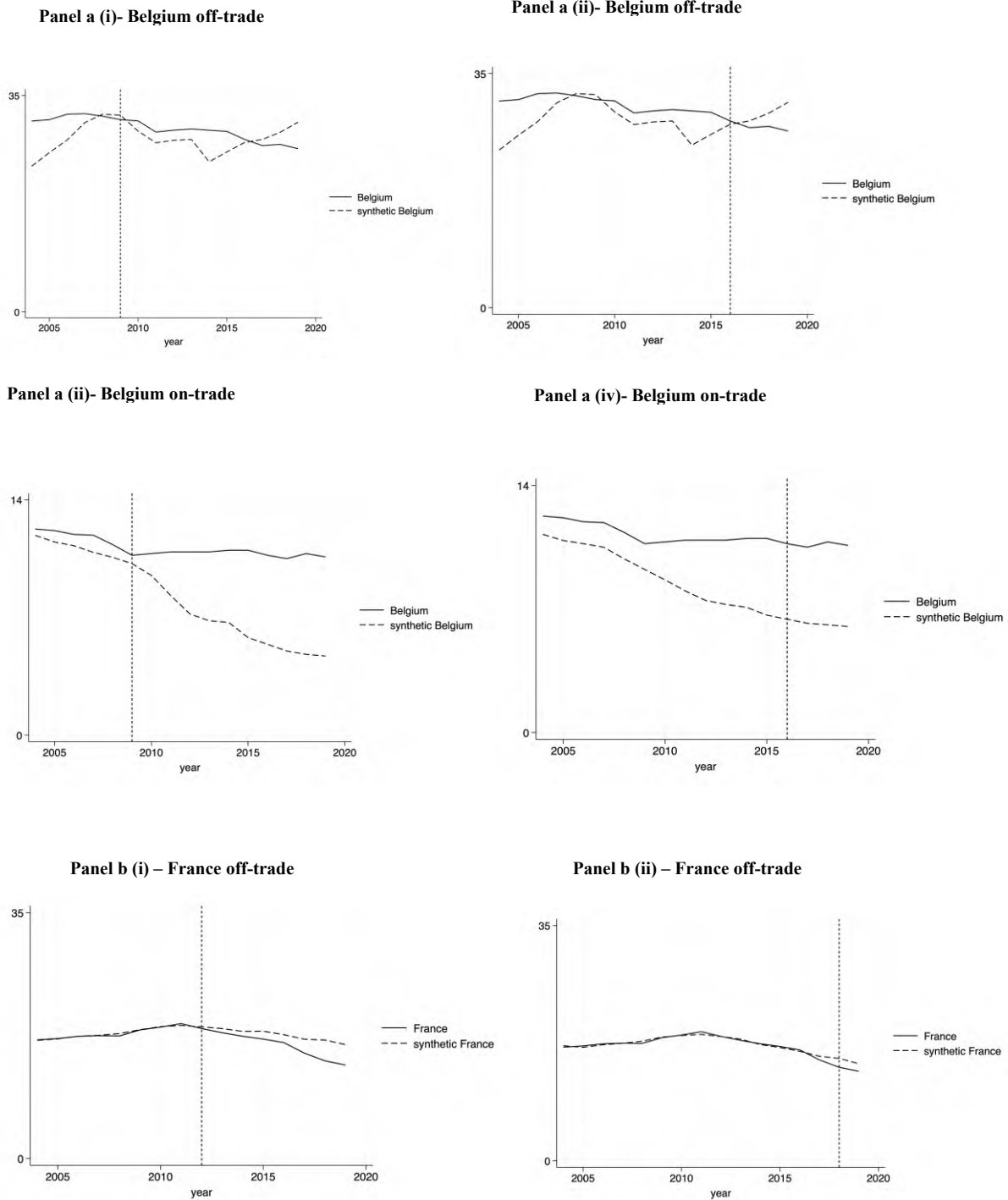


#### On-trade - control countries

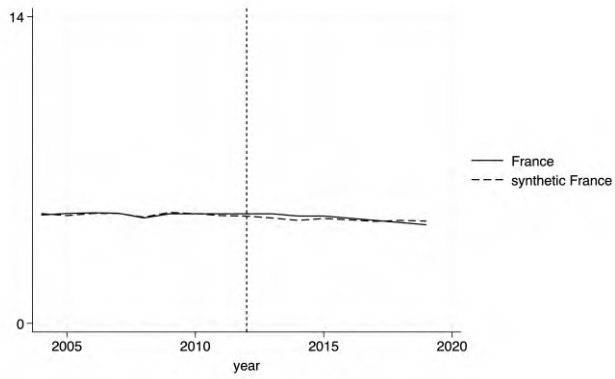


Note: Trends in average per capita sales volumes of regular cola carbonates over the study period, distinguishing between treated and control countries (source: Euromonitor Data). Off-trade sales (Panel A) and on-trade sales (Panel B) are shown separately.

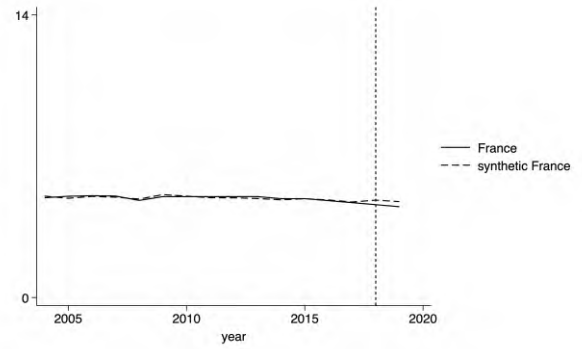
**Figure 2 – Treatment Effect - Total Sales of Regular Cola Carbonates (per capita off- and on-trade sales volume of regular cola carbonates)**



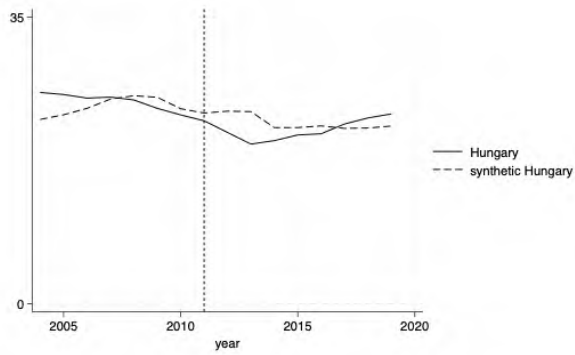
**Panel b (iii) – France on- trade**



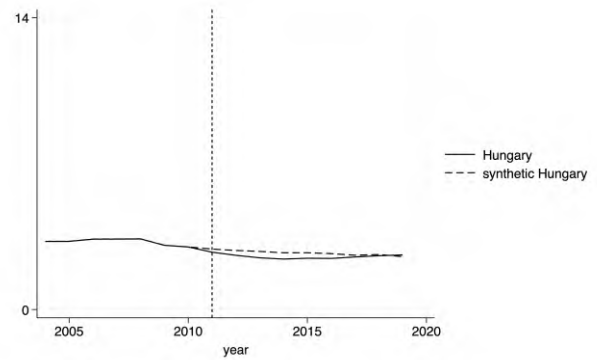
**Panel b (iv) - France on- trade**



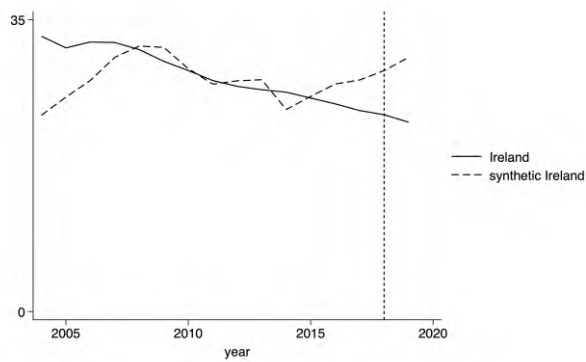
**Panel c (i) -Hungary off-trade**



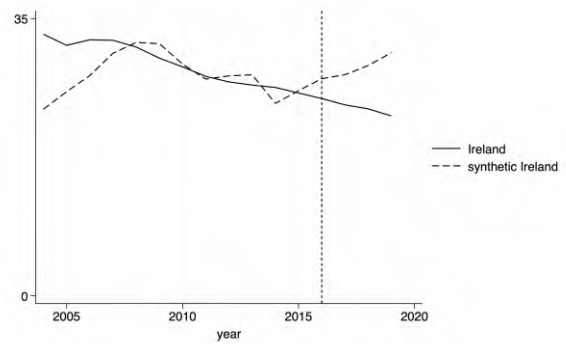
**Panel c (ii)- Hungary on-trade**



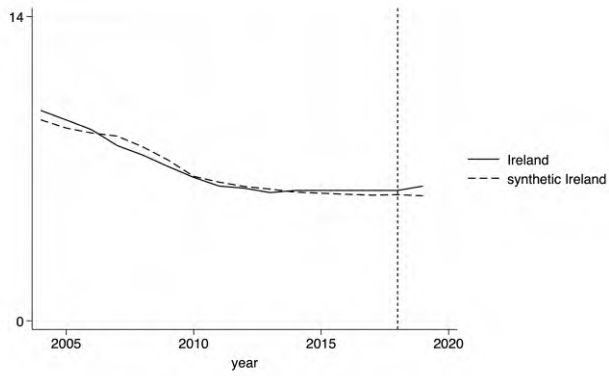
**Panel d (i) – Ireland off-trade**



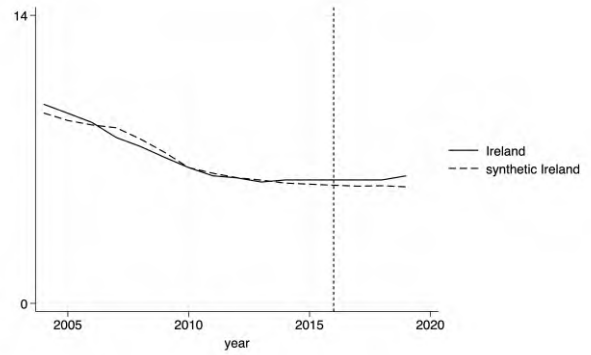
**Panel d (ii) - Ireland off-trade**



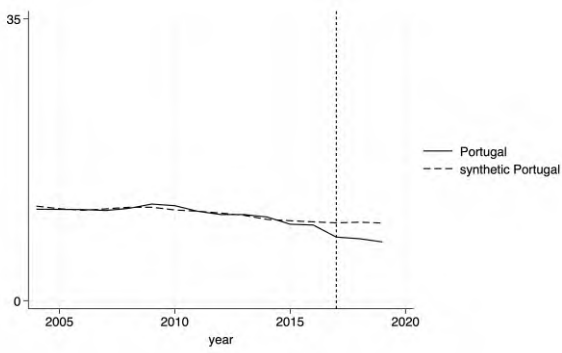
**Panel d (iii) - Ireland on-trade**



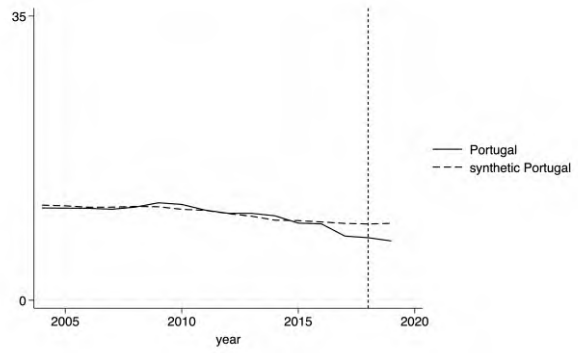
**Panel d (iv) - Ireland on-trade**



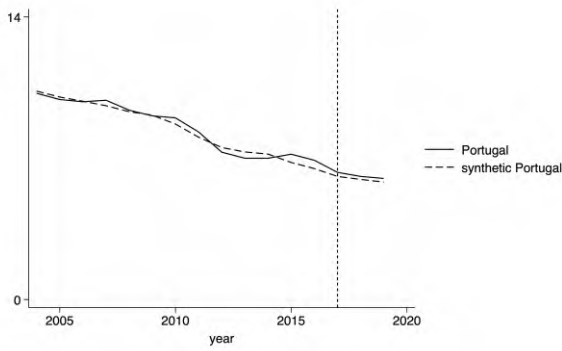
**Panel e (i) - Portugal off-trade**



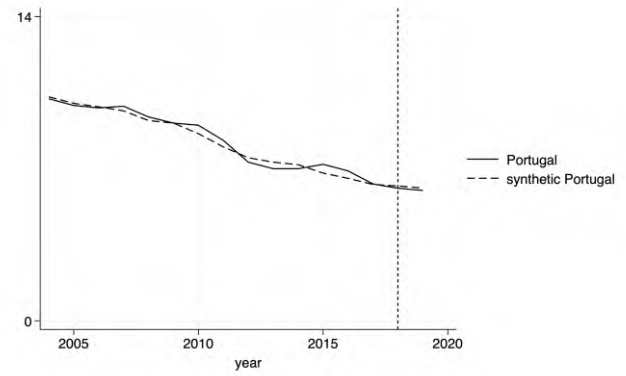
**Panel e (ii) - Portugal off-trade**



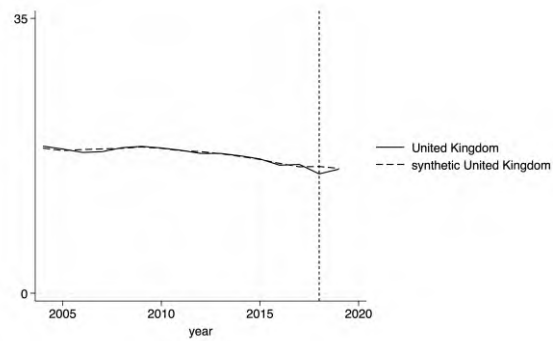
**Panel e (iii) - Portugal on-trade**



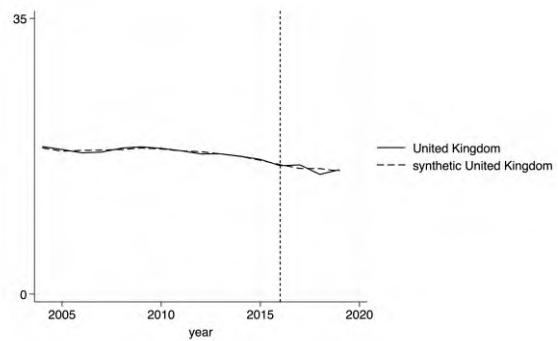
**Panel e (iv) - Portugal on-trade**

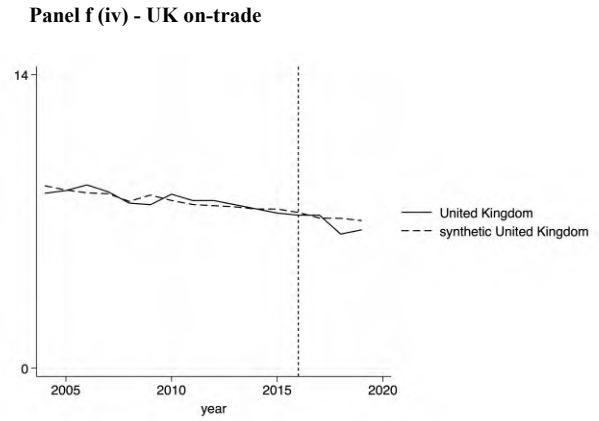
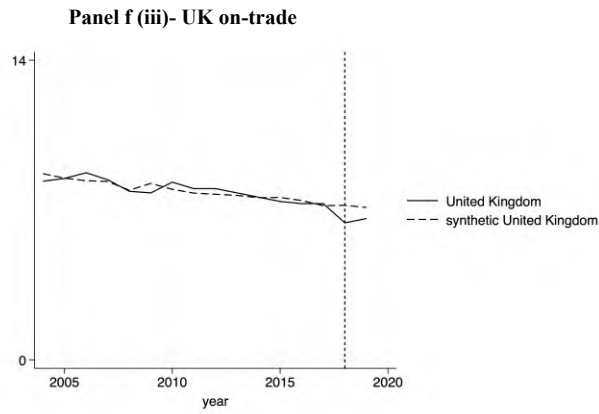


**Panel f (i) - UK off-trade**



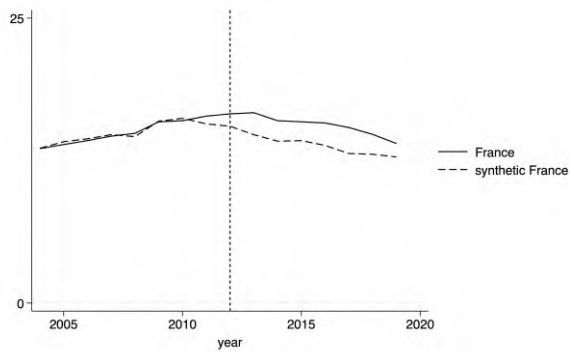
**Panel f (ii) UK off-trade**



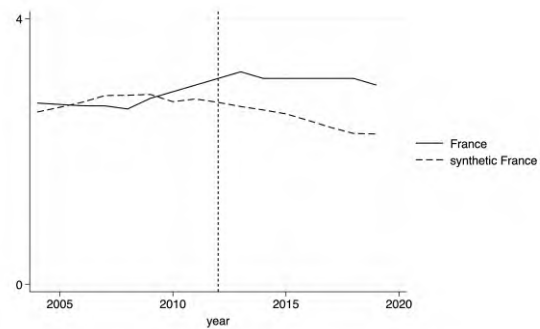


**Figure 3 – Consumers’ Substitution. Treatment Effect - Total Sales of 100% fruit juice (per capita off- and on-trade sales volume of 100% fruit juice). Euromonitor data.**

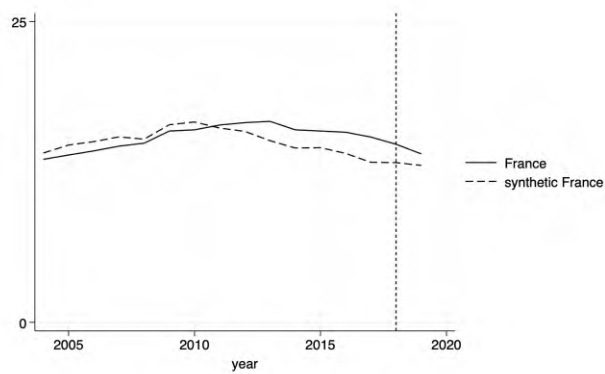
**Panel a(i)- France off-trade**



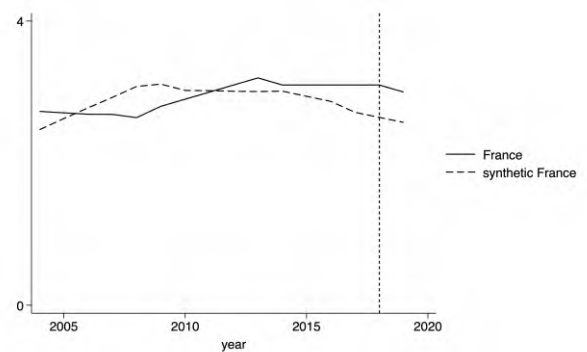
**Panel a(ii) -- France on-trade**



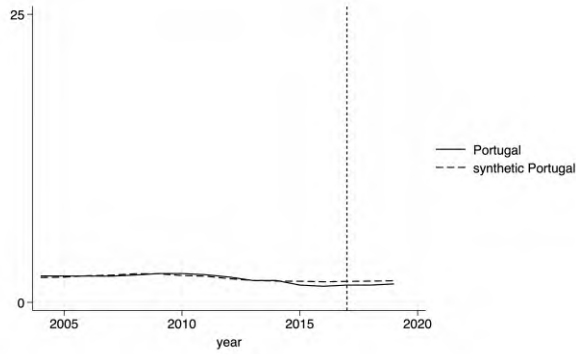
**Panel a(iii)- France off-trade**



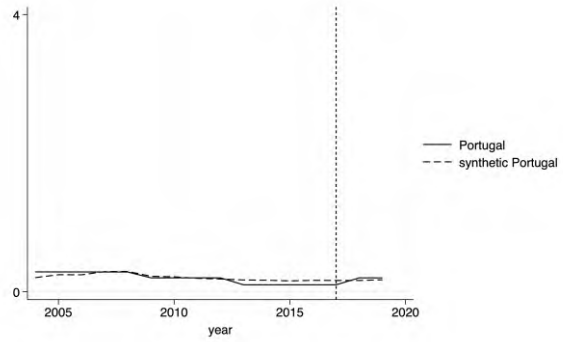
**Panel a(iv)- France on-trade**



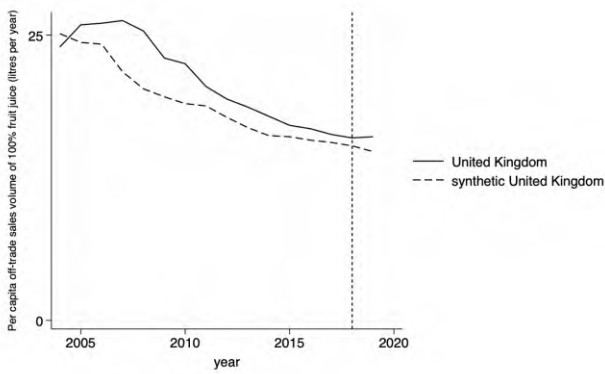
**Panel b(i) – Portugal off-trade**



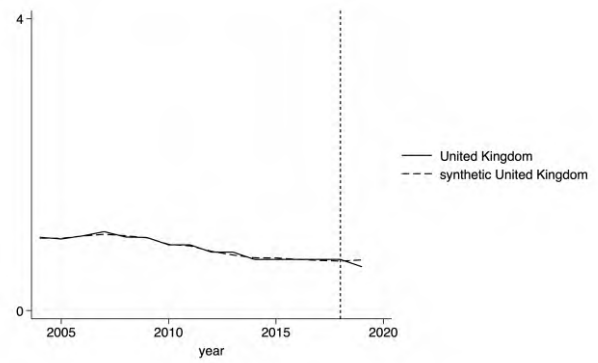
**Panel b(ii) – Portugal on-trade**



**Panel c(i) – UK off-trade**

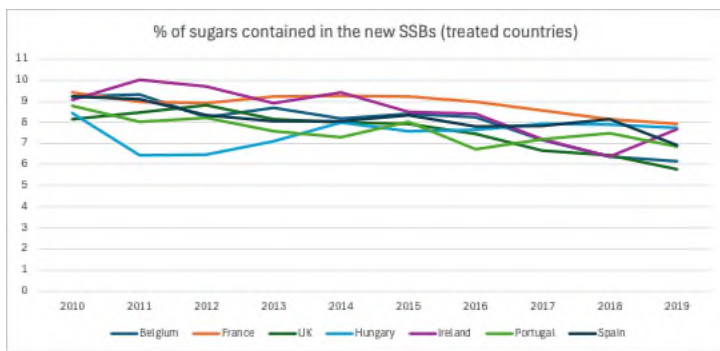


**Panel c(ii) - UK on-trade**

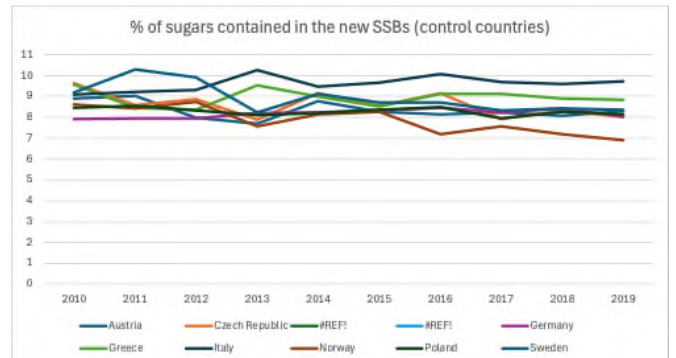


**Figure 4 –Average sugar content (grams per 100 ml) of newly launched or relaunched SSBs, by country type: treated vs control, 2010–2019\*. Mintel data.**

**Treated countries**

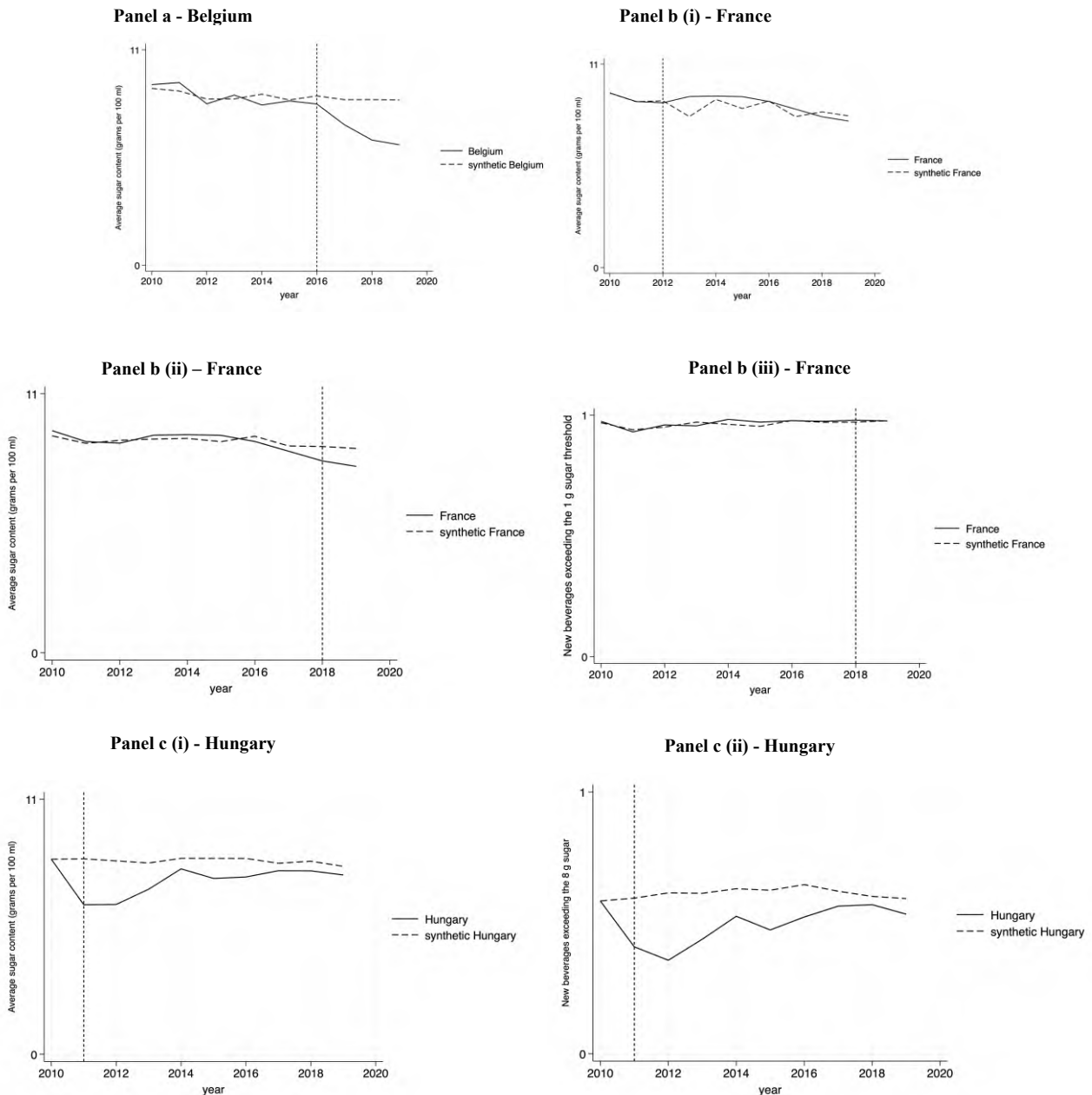


**Control countries**

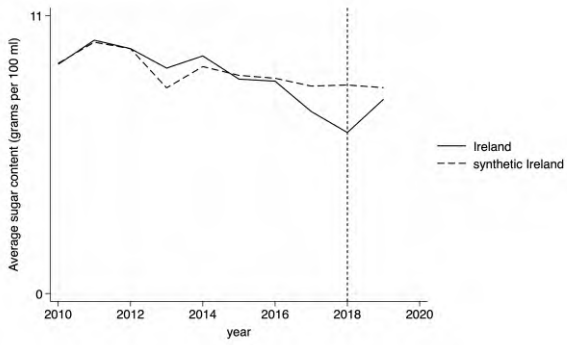


\*Note: Trends in the average sugar content of newly relaunched sugar-sweetened beverages (SSBs) over the period 2010–2019, distinguished between treated countries and control countries, highlighting differences in reformulation patterns (source: Mintel).

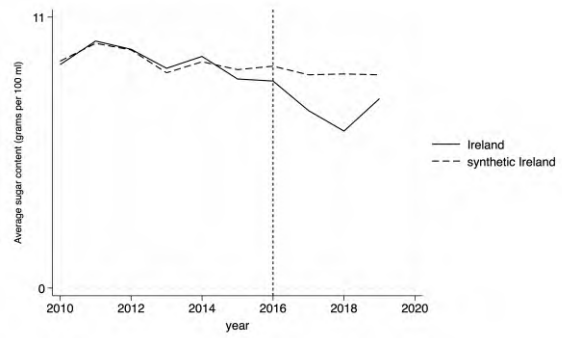
**Figure 5 – Treatment Effect - Producers’ Reformulation. Mintel data.**



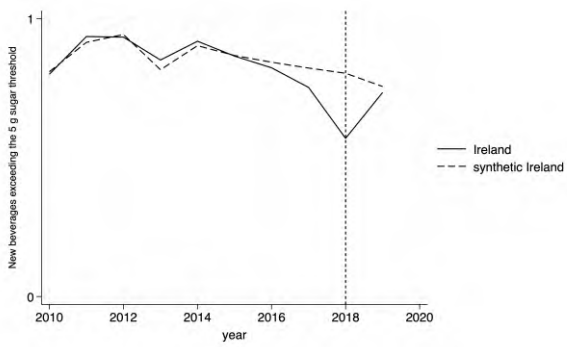
**Panel d(i) - Ireland**



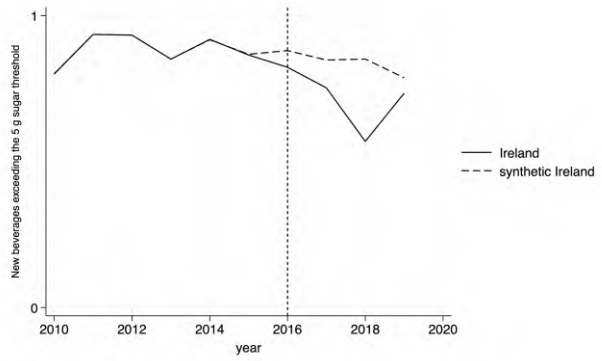
**Panel d(ii) - Ireland**



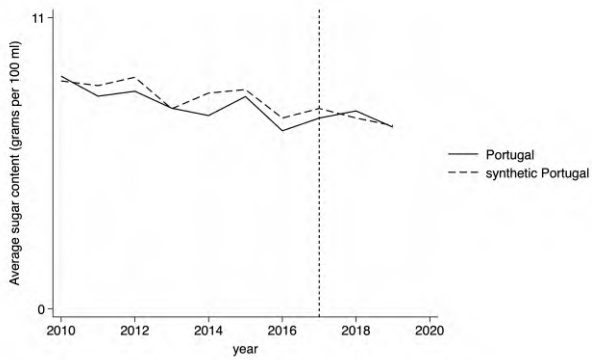
**Panel d(iii) - Ireland**



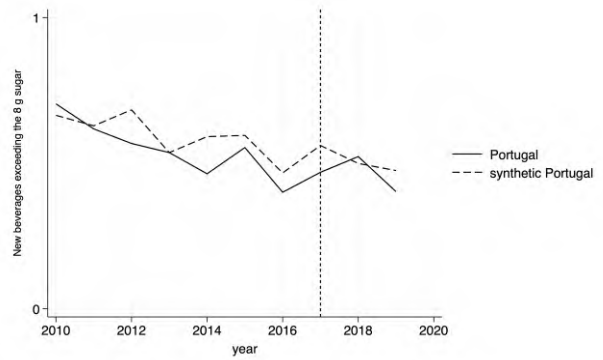
**Panel d(iv) - Ireland**

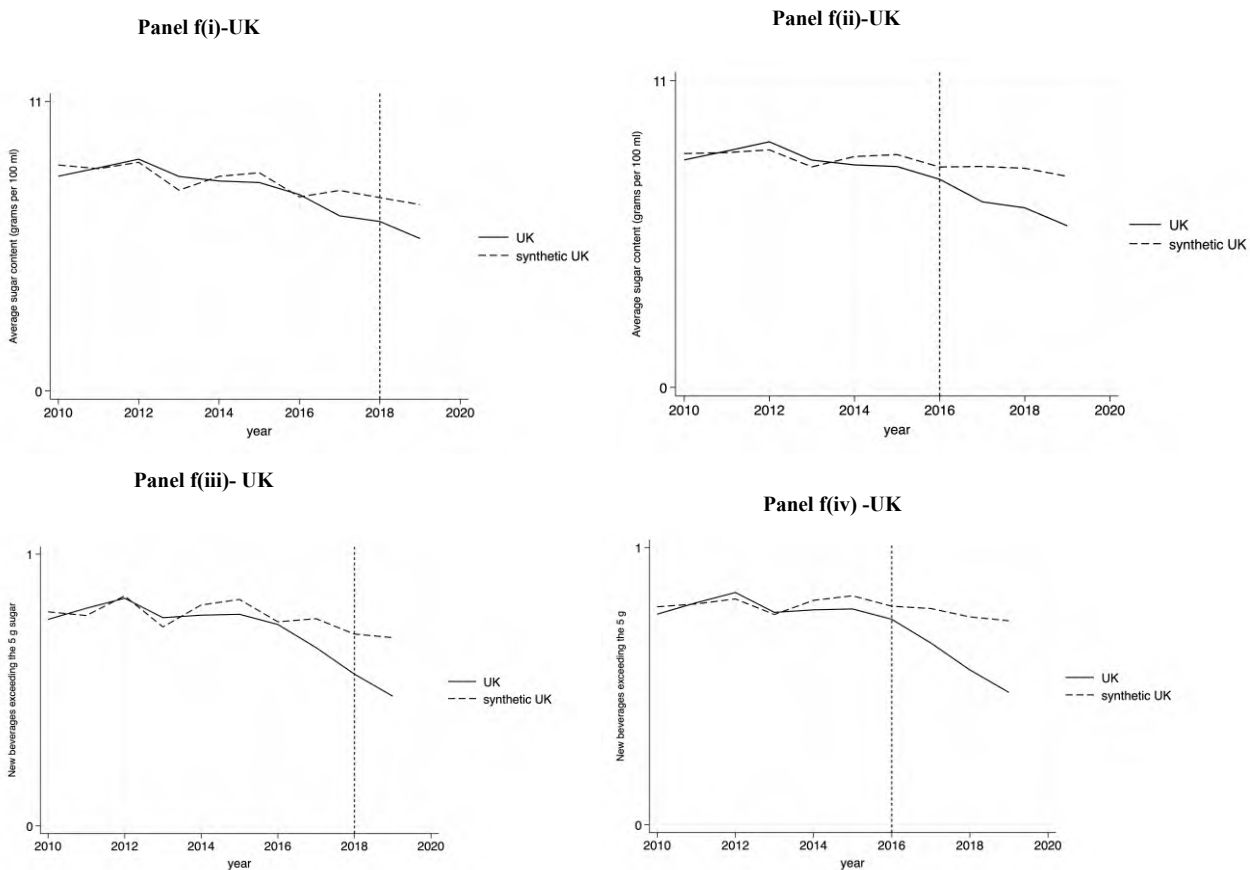


**Panel e(i) - Portugal**

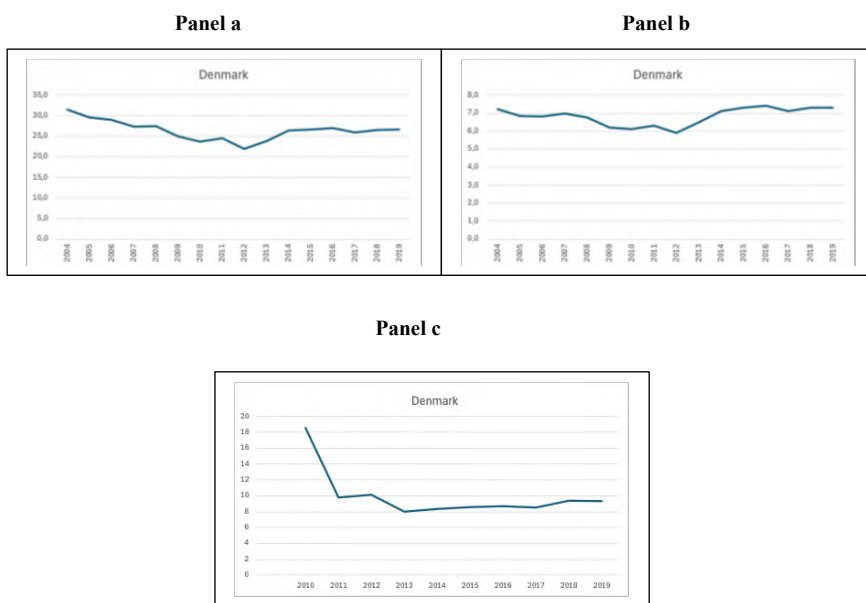


**Panel e(ii) -Portugal**



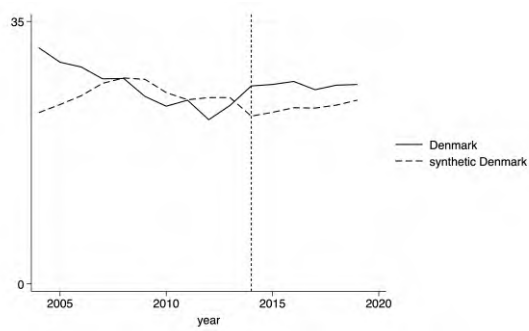


**Figure 6 – Per capita sales of regular cola carbonates in Denmark, 2004–2019 off-trade (a), on-trade (b) and average sugar content (g/100 ml) of newly launched/relaunched SSBs, 2010–2019 (c)**

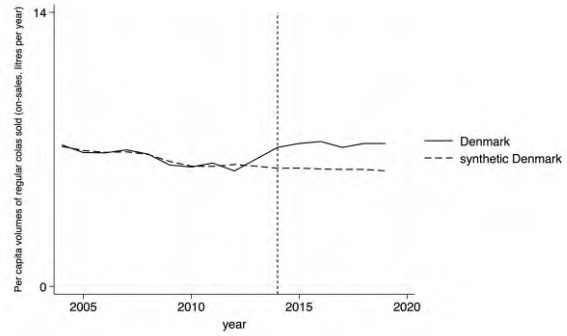


**Figure 7 – Treatment Effect - regular cola carbonates in Denmark, 2004–2019 off-trade (a), on-trade (b) and average sugar content (g/100 ml) of newly launched/relaunched SSBs, 2010–2019 (c)**

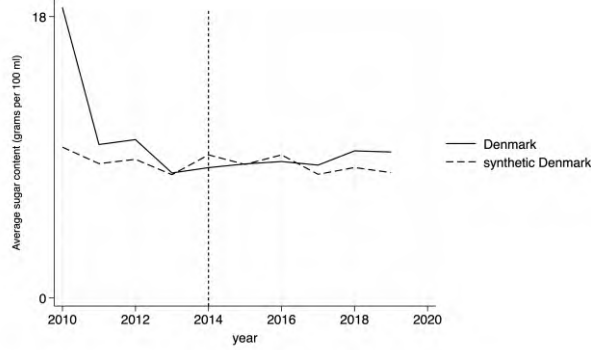
**Panel a – Denmark off-trade**



**Panel b – Denmark on-trade**



**Panel c – Denmark reformulation**



**Table 1A. Treatment effect (yearly per capita litres). Regular cola carbonates, off-trade sales. Euromonitor data.**

<b>Years</b>	<b>Belgium 2009</b>	<b>Belgium 2016</b>	<b>France 2012</b>	<b>France 2018</b>	<b>Hungary 2011</b>	<b>Ireland 2018</b>	<b>Ireland 2016</b>	<b>Portugal 2017</b>	<b>UK 2018</b>	<b>UK 2016</b>
2009	0.95									
	<i>0.93</i>									
2010	1.13									
	<i>0.93</i>									
2011	1.15				-0.05					
	<i>1.00</i>				<i>0.79</i>					
2012	1.14		-0.23		-0.12					
	<i>0.93</i>		<i>0.50</i>		<i>0.50</i>					
2013	1.15		-0.60		-0.19					
	<i>1.00</i>		<i>0.50</i>		<i>0.36</i>					
2014	1.55		-0.70		-0.08					
	<i>0.64</i>		<i>0.36</i>		<i>0.64</i>					
2015	1.32		-1.12		-0.05					
	<i>0.86</i>		<i>0.36</i>		<i>0.86</i>					
2016	1.04	1.04	-1.12		-0.04		0.80			-0.13
	<i>1.00</i>	<i>1.00</i>	<i>0.43</i>		<i>1.00</i>		<i>0.79</i>			<i>0.93</i>
								-		
2017	0.92	0.92	-1.98 ***		0.03		0.71	1.77 ***		0.45

	<i>1.00</i>	<i>1.00</i>	<i>0.00</i>	-	<i>1.00</i>		<i>0.79</i>	<i>0.00</i>		<i>0.36</i>
2018	0.85	0.85	-2.97 ***	1.32 ***	0.07	0.64	0.62	2.05 ***	-0.93 *	-0.73
	<i>1.00</i>	<i>1.00</i>	<i>0.00</i>	<i>0.00</i>	<i>1.00</i>	<i>0.43</i>	<i>0.86</i>	<i>0.00</i>	<i>0.07</i>	<i>0.29</i>
				-				-		
2019	0.71	0.71	-2.91 *	1.13 *	0.09	0.52	0.50	2.35 *	-0.10	0.19
	<i>0.93</i>	<i>1.00</i>	<i>0.07</i>	<i>0.07</i>	<i>0.93</i>	<i>0.57</i>	<i>0.57</i>	<i>0.07</i>	<i>0.93</i>	<i>0.93</i>
<b>RMSPE</b>	0.16	0.13	0.16	0.24	0.07	0.13	0.13	0.30	0.20	0.18

RMSPE indicates Root Mean Squared Percentage Error. P-values in italics: \*indicates  $P < 0.1$ ; \*\*indicates  $P < 0.05$ ; \*\*\*indicates  $P < 0.001$

**Table 1B. Treatment effect (yearly per capita litres). Regular cola carbonates, on-trade sales. Euromonitor data.**

<b>Years</b>	<b>Belgium 2009</b>	<b>Belgium 2016</b>	<b>France 2012</b>	<b>France 2018</b>	<b>Hungary 2011</b>	<b>Ireland 2018</b>	<b>Ireland 2016</b>	<b>Portugal 2017</b>	<b>UK 2018</b>	<b>UK 2016</b>
2009	1.12									
	<i>1.00</i>									
2010	1.34									
	<i>0.86</i>									
2011	1.87				-0.15 *					
	<i>0.71</i>				<i>0.07</i>					
2012	2.60		0.10		-0.23 *					
	<i>0.79</i>		<i>0.36</i>		<i>0.07</i>					

2013	2.96		0.19		-0.31	*					
	<i>0.79</i>		<i>0.29</i>		<i>0.07</i>						
2014	3.13		0.20		-0.30	*					
	<i>0.79</i>		<i>0.21</i>		<i>0.07</i>						
2015	4.37		0.11		-0.26	*					
	<i>0.71</i>		<i>0.57</i>		<i>0.07</i>						
2016	4.83	2.49	0.07		-0.23	*		1.81			-0.13
	<i>0.71</i>	<i>0.36</i>	<i>0.71</i>		<i>0.07</i>			<i>0.57</i>			<i>0.71</i>
2017	5.52	2.46	0.05		-0.08	*		2.01	0.20		0.14
	<i>0.64</i>	<i>0.71</i>	<i>0.86</i>		<i>0.07</i>			<i>0.79</i>	<i>0.79</i>		<i>1.00</i>
2018	6.47	2.63	-0.10	-0.23	-0.06	*	0.20	1.92	0.15	-0.82	-0.75
	<i>0.64</i>	<i>0.79</i>	<i>0.57</i>	<i>0.14</i>	<i>0.07</i>		<i>0.86</i>	<i>0.86</i>	<i>0.93</i>	<i>0.14</i>	<i>0.36</i>
2019	6.51	2.60	-0.17	-0.25	0.08	*	0.45	3.43	0.18	-0.53	-0.44
	<i>0.64</i>	<i>0.79</i>	<i>0.36</i>	<i>0.07</i>	<i>0.07</i>	*	<i>0.57</i>	<i>0.64</i>	<i>0.93</i>	<i>0.43</i>	<i>0.71</i>
<b>RMSPE</b>	0.06	0.28	0.06	0.06	0.00		0.26	0.26	0.25	0.23	0.25

*RMSPE indicates Root Mean Squared Percentage Error. P-values in italics: \*indicates P<0.1; \*\*indicates P<0.05; \*\*\*indicates P<0.001*

**Table 2A. Treatment effect (yearly per capita litres). 100% fruit juices, off-trade sales. Euromonitor data.**

<b>Years</b>	<b>France 2012</b>	<b>France 2018</b>	<b>Portugal 2017</b>	<b>UK 2018</b>
2009				
2010				
2011				
2012	1.09 *** <i>0.07</i>			
2013	1.92 *** <i>0.07</i>			
2014	1.80 <i>0.14</i>			
2015	1.65 <i>0.14</i>			
2016	1.97 <i>0.14</i>			
2017	2.28 <i>0.14</i>		-0.32 <i>0.21</i>	
2018	1.75	1.52	-0.34	1.11

	<i>0.21</i>	<i>0.29</i>	<i>0.21</i>	<i>0.71</i>
2019	1.18	0.96	-0.28	1.21
	<i>0.29</i>	<i>0.57</i>	<i>0.36</i>	<i>0.64</i>
<b>RMSPE</b>	0.30	1.13	0.17	0.12

*RMSPE indicates Root Mean Squared Percentage Error. P-values in italics: \*indicates P<0.1; \*\*indicates P<0.05; \*\*\*indicates P<0.001*

**Table 2B. Treatment effect (yearly per capita litres). 100% fruit juices, on-trade sales. Euromonitor data.**

<b>Years</b>	<b>France 2012</b>	<b>France 2018</b>	<b>Portugal 2017</b>	<b>UK 2018</b>
2009				
2010				
2011				
2012	0.36			
	<i>0.21</i>			
2013	0.52			
	<i>0.21</i>			
2014	0.48			
	<i>0.36</i>			

2015	0.53				
	<i>0.29</i>				
2016	0.63				
	<i>0.36</i>				
2017	0.74		-0.06		
	<i>0.21</i>		<i>0.21</i>		
2018	0.83	0.46	0.04	0.02	
	<i>0.21</i>	<i>0.14</i>	<i>0.57</i>	<i>0.29</i>	
2019	0.74	0.43	0.03	-0.09	***
	<i>0.21</i>	<i>0.21</i>	<i>0.64</i>	<i>0.00</i>	
<b>RMSPE</b>	0.14	0.23	0.05	0.02	

*RMSPE indicates Root Mean Squared Percentage Error. P-values in italics: \*indicates P<0.1; \*\*indicates P<0.05; \*\*\*indicates P<0.001*

**Table 3. Treatment effect. Average grams of sugar per 100 ml in the newly launched or relaunched soft drinks. Percentage of newly launched or relaunched drinks with at least 1 g of sugars (France 2018), or with at least 5 grams of sugar (Ireland 2018, Ireland 2016, UK 2018, UK 2016), or with at least 8 g of sugars (Hungary 2011, Portugal 2017). Mintel data.**

Years	Belgium 2016	France 2012	France 2018		Hungary 2011		Ireland 2018	
	Av. g sugar	Av. g sugar	Av. g sugar	% drinks	Av. g sugar	% drinks	Av. g sugar	% drinks

						>1g sugar		>8g sugar			>5g sugar	
2011								-1.98			-0.19	***
								<i>0.25</i>			<i>0.00</i>	
2012			-0.11					-1.88			-0.26	***
			<i>0.50</i>					<i>0.50</i>			<i>0.00</i>	
2013			1.08					-1.13			-0.18	
			<i>0.38</i>					<i>0.63</i>			<i>0.13</i>	
2014			0.18					-0.46			-0.11	
			<i>0.5</i>					<i>0.50</i>			<i>0.13</i>	
2015			0.64					-0.86			-0.15	***
			<i>0.25</i>					<i>0.38</i>			<i>0.00</i>	
2016	-0.41		-0.02					-0.80			-0.12	
	<i>0.63</i>		<i>0.5</i>					<i>0.38</i>			<i>0.13</i>	
2017	-1.28	***	0.41					-0.32			-0.06	
	<i>0.00</i>		<i>0.5</i>					<i>0.75</i>			<i>0.13</i>	
2018	-2.07	***	-0.26	-0.61	***	0.01		-0.41			-0.03	
	<i>0.00</i>		<i>0.5</i>	<i>0.00</i>		<i>0.13</i>		<i>0.50</i>			<i>0.13</i>	
2019	-2.29	***	-0.28	-0.76	***	0.00		-0.37			-0.06	
	<i>0.00</i>		<i>0.25</i>	<i>0.00</i>		<i>1.00</i>		<i>0.38</i>			<i>0.13</i>	
<b>RMSPE</b>	0.33		0.00	0.19		0.01		0.00			0.00	
											0.48	
											0.03	

Years	Ireland 2016		Portugal 2017		UK 2018		UK 2018 >5g		UK 2016		UK 2016 >5g	
	Av. g sugar	% drinks >5g sugar	Av. g sugar	% drinks >8g sugar	Av. g sugar	% drinks >5g sugar	Av. g sugar	% drinks >5g sugar	Av. g sugar	% drinks >5g sugar	Av. g sugar	% drinks >5g sugar
2016	-0.60 <i>0.25</i>	-0.06 <i>0.00</i> ***							-0.44 <i>0.50</i>		-0.05 <i>0.25</i> ***	
2017	-1.45 <i>0.00</i> ***	-0.10 <i>0.00</i> ***	-0.36 <i>0.88</i>	-0.09 <i>0.13</i>					-1.27 <i>0.00</i> ***		-0.12 <i>0.00</i> ***	
2018	-2.32 <i>0.00</i> ***	-0.28 <i>0.00</i> ***	0.27 <i>0.25</i>	0.02 <i>0.75</i>	-0.91 <i>0.00</i> ***	-0.15 <i>0.00</i> ***			-1.42 <i>0.00</i> ***		-0.19 <i>0.00</i> ***	
2019	-0.97 <i>0.00</i> ***	-0.05 <i>0.00</i> ***	-0.06 <i>0.75</i>	-0.07 <i>0.38</i>	-1.29 <i>0.00</i> ***	-0.22 <i>0.00</i> ***			-1.78 <i>0.00</i> ***		-0.26 <i>0.00</i> ***	
<b>RMSPE</b>	0.21	0.00	0.46	0.07	0.44	0.05			0.28		0.03	

*RMSPE indicates Root Mean Squared Percentage Error. P-values in italics: \*indicates P<0.1; \*\*indicates P<0.05; \*\*\*indicates P<0.001*

**Table 4. Treatment effect (yearly per capita litres) for Denmark. Regular cola carbonates, off-trade and on-trade sales. Euromonitor data.**

<b>Years</b>	<b>Denmark 2014 Off-trade sales</b>	<b>Denmark 2014 On-trade sales</b>	
2014	1.45 <i>0.64</i>	1.07 <i>0.00</i>	<b>***</b>
2015	1.42 <i>0.86</i>	1.26 <i>0.00</i>	<b>***</b>
2016	1.40 <i>0.86</i>	1.40 <i>0.00</i>	<b>***</b>
2017	1.29 <i>1.00</i>	1.12 <i>0.00</i>	<b>***</b>
2018	1.33 <i>1.00</i>	1.32 <i>0.07</i>	<b>*</b>
2019	1.29 <i>1.00</i>	1.40 <i>0.00</i>	<b>***</b>
<b>RMSPE 0.14</b>		<b>0.02</b>	

*RMSPE indicates Root Mean Squared Percentage Error. P-values in italics: \*indicates P<0.1; \*\*indicates P<0.05; \*\*\*indicates P<0.001*

## APPENDIX

**Table A.1 - Sugar-Sweetened Beverage (SSB) Taxes in Selected European Countries**

<i>Country</i>	<i>Year of Introduction / Revision</i>	<i>Scope of Tax</i>	<i>Tax Design and Rates</i>	<i>Exemptions / Additional Notes</i>
<b>Belgium</b>	2009; revised 2015 (effective 2016)	Soft drinks, including non-alcoholic beverages, mineral and carbonated waters with added sugars, sweeteners or flavourings; liquid and solid concentrates	Excise duty of €0.41 per litre on drinks with added sugars or sweeteners and liquid concentrates; €0.68 per kg on powdered or solid concentrates	Applies to both sugar- and sweetener-containing beverages
<b>France</b>	2012; revised 2018	Sugar-sweetened and artificially sweetened beverages	Progressive tax based on sugar content, ranging from €0.03 per litre ( $\leq 1$ g sugar/100 ml) to €0.24 per litre (15 g sugar/litre), plus €0.0205 per kg of added sugar above this threshold	Reform aimed at incentivising product reformulation
<b>Hungary</b>	2011	Soft drinks containing high levels of sugar	Applies to beverages containing more than 8 g of sugar per 100 ml	Part of the Public Health Product Tax (NETA); fruit and vegetable juices and nectars ( $\geq 50\%$ fruit/vegetable content) are exempt
<b>Ireland</b>	Announced 2016; implemented 2018; amended 2019	Non-alcoholic, water-based and fruit-based drinks with added sugar; plant protein drinks; certain milk-based beverages; concentrates	Tiered excise duty: €0.16 per litre (5–8 g sugar/100 ml); €0.24 per litre ( $\geq 8$ g sugar/100 ml)	Beverages containing $< 5$ g sugar/100 ml are exempt
<b>Portugal</b>	2017; revised 2018 and 2019	Mineral, flavoured and carbonated waters with added sugars or sweeteners; concentrates	Multi-tier excise tax: €0.01 per litre ( $< 2.5$ g sugar/100 ml); €0.06 (2.5–4.9 g); €0.08 (5–7.9 g); €0.20 ( $\geq 8$ g)	Juices, nectars, and milk-, soy- or rice-based drinks are excluded

<b>United Kingdom</b>	Announced 2016; implemented 2018	Pre-packaged soft drinks with added sugar	Two-tier levy: £0.18 per litre (5– 8 g sugar/100 ml); £0.24 per litre (>8 g sugar/100 ml)	Exemptions include milk- based drinks, pure fruit juices, powder-based drinks, and beverages with >1.2% alcohol
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