ERASMUS UNIVERSITY ROTTERDAM

Erasmus School of Economics

# The Impact of the French Soda Tax on Soda and Alcohol Consumption in France

## An Application of the Synthetic Control Method

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Bachelor Thesis [Economics and Business Economics]

"Sugar, rum, and tobacco are commodities which are nowhere necessaries of life, which are become objects of almost universal consumption, and which are therefore extremely proper subjects of taxation" (Adam Smith, 1776, Book V, ch. III, p. 3).

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## Abstract

Soda consumption is a significant contributor to excess sugar consumption, and thus to the ongoing obesity pandemic. Moreover, there are externalities and internalities present in the soda market. Partly for these reasons, more and more countries around the world are introducing a sugary drink tax. France introduced a lump-sum tax of 7.16 Eurocents per litre on all sweetened beverages in 2012. This paper assesses the impact of the introduction of the soda tax in France on the consumption of sodas and alcohol in France. By using the synthetic control method, the statistically optimal counterfactual consumption trend is approximated as a weighted average of western countries that did not implement a soda tax. The statistical significance of the estimated treatment effects is assessed by in-space and in-time placebo tests. The introduction of the soda tax in France had a positive effect on juice consumption and a negative effect on carbonates consumption. Effects on soda and alcohol expenditures were ambiguous. However, the predictor balance and outcomes of the placebo tests suggest that these results cannot be attributed to the introduction of the soda tax.

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## Introduction

The American Medical Association officially recognized obesity as a disease in 2013. This was mainly done to increase the legitimacy of, and attention for the condition. From 1975 to 2016 the prevalence of obesity nearly tripled globally, without any sight of flattening the curve. In 2016, 39 percent of adults were overweight and 13 percent was obese. For the western world, the numbers become even more staggering. In Europe roughly 63 percent of adults was overweight and 22 percent was obese in 2016. In the United States, around 70 percent of the adult population was overweight and a startling amount of 37 percent was obese in 2016. The worldwide consensus is very clear: obesity is a pandemic. This pandemic has allowed cardiovascular diseases to become the main cause of death around the globe with a share of 31% of all deaths. Excess fat is considered to be preventable to a great extent, mainly by adopting a healthier lifestyle (Meldrum, Morris & Gambrone, 2017; WHO, 2021; Ritchie & Roser, 2017; Ritchie & Roser, 2018).

The American Heart Association identified sugar-sweetened drinks as the main contributor to excess sugar consumption. This excess consumption contributes at least in part to the ongoing obesity epidemic. However, sugar consumption does not only affect health adversely through its effect on weight, but also in itself. High glucose intake can namely result in inflammation, insulin resistance and high blood pressure through an increase in uric acid. If a soda tax is successful in reducing soda and sugar consumption, this can lead to significant improvements in the health of citizens, fewer deaths and less healthcare costs. It should however be noted that these effects can only arise when sugary drinks are substituted by healthier alternatives like water (Johnsen et al., 2007; Malik, Popkin, Bray, Després & Hu, 2010).

Some consumers are unable to sufficiently take the adverse long-term health effects of soda consumption into account when making consumption decisions. This can lead to an overconsumption of sugary drinks from the perspective of the consumer itself. These internalities may arise from several behavioural biases like self-control bias or present bias. Another problem that arises in the context of soda consumption are externalities. They occur when costs on society that are the result of excessive soda consumption and subsequent health problems are not considered when an individual chooses the amount of soda it consumes. (Allcott, Lockwood & Taubinsky, 2019a). To try to correct the internalities and externalities that are present in soda consumption, countries like France, The United Kingdom, Finland and

Thailand already started taxing soda, while others are still debating the introduction of a soda tax (World bank, 2020).

France introduced a soda tax of roughly 7 Eurocents per litre in 2012 (Law 2011-1977). The details of this tax will be set out on the next chapter. Figure 1 shows the French juice and carbonates consumption trend from 2006 to 2019. Consumption peaked in 2011 and has been steadily declining since. It is however unclear whether this decline can be attributed to the introduction of the French sweetened drink tax. The average soda consumption in the European Union plus the United States, Canada, Australia and New Zealand has already been on a downward trend since 2007, as shown in figure 2. So, there might be other confounding factors driving the consumption trend in France downwards. The possible reduction of soda consumption might be substituted by consumption of equally harmful alcoholic drinks. This leads to the main research question: What is the causal impact of the French soda tax on soda and alcohol consumption in France? This paper thus investigates whether the French soda tax is successful in reducing soda consumption and whether consumers substitute their intake with alcoholic drinks.

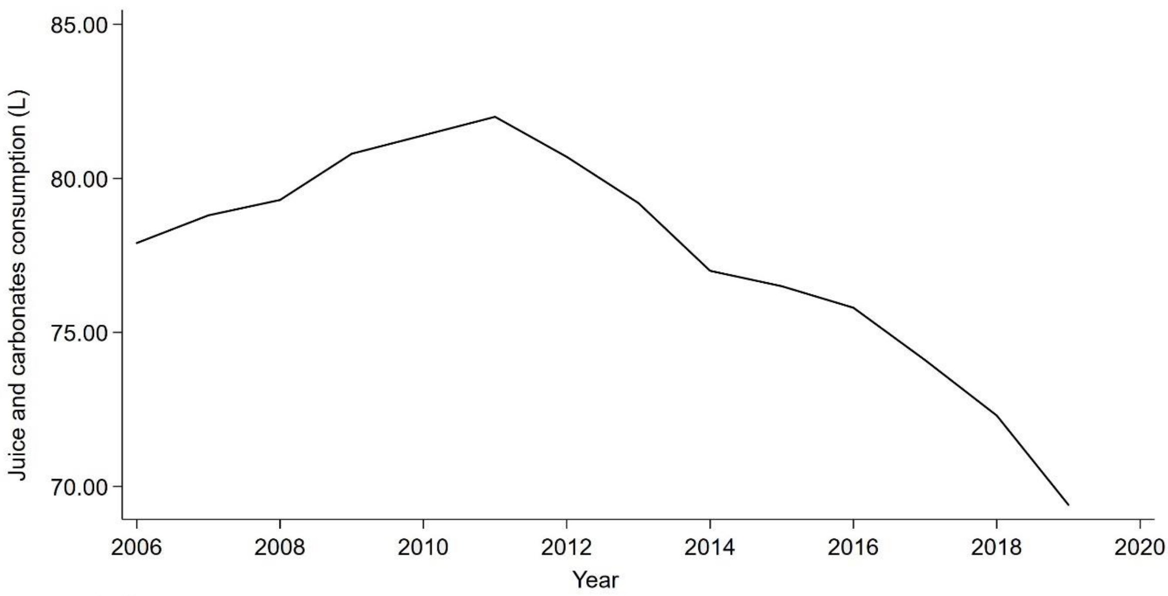


Figure 1 Juice and carbonates consumption trend in France from 2006-2019

Notes: In this figure the trend of juice and carbonates consumption in France is shown for the period 2006-2019. With the consumption in litres per capita on the y-axis and the year on the x-axis. The data was obtained from the Passport Euromonitor database.

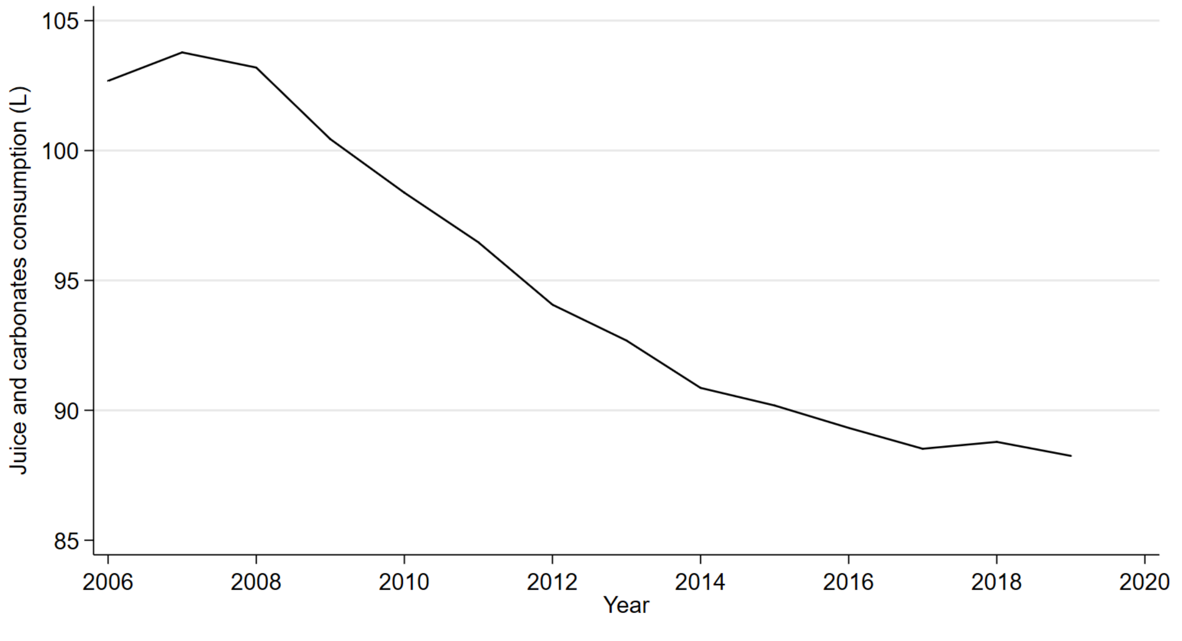


Figure 2 Average juice and carbonates consumption trend for all countries in the sample from 2006-2019

Notes: In this figure the average trend of juice and carbonates consumption for all countries in the sample is shown for the 2006-2019 period. The included countries are reported in table A1. The consumption in litres per capita is on the y-axis and the year on the x-axis. The data was obtained from the Passport Euromonitor database.

The biggest problem with regard to analysing the causal effect of a soda tax on consumption, or even to analyse any causal effect, is the approximation of the counterfactual. What would have happened if a policy would not have been implemented? Earlier studies had significant issues with estimating the true counterfactual in the present case of the introduction of a soda tax. They either used a neighbouring country (Capacci, Allais, Bonnet & Mazzocchi, 2019) or a non-taxed substitute like water (Gonçalves & Dos Santos, 2020) as the comparable unit in a difference-in-difference design. Each lacking comparative capabilities to be a good control group. This paper aims to solve this issue by implementing the synthetic control method, where the statistically optimal counterfactual consumption trend is constructed based on a weighted average of western countries that did not implement a soda tax. The counterfactuals are optimized by minimizing the root mean squared prediction error. The result is an estimation of the treatment effect for every year after the introduction of the tax. Consequently, the synthetic control method is able to capture long-term effects. This is in contrast to the mentioned earlier studies that used a difference-in-difference design, where the authors only compare two points in time.

The data needed to execute the method and answer the research question is obtained from the following sources. Data on soda expenditures, carbonates consumption, juice consumption and alcohol expenditures is retrieved from the Passport Euromonitor database. Data on soda consumption predictors is obtained from the Our World in Data database. The results show that the effect of the introduction of the French soda tax on soda expenditures is ambiguous. The effect on carbonates consumption is negative and the effect on juice consumption is positive. There are on average no substitution effects towards alcohol consumption found. To assess whether the found treatment effects can be attributed to the introduction of the soda tax, in-place and in-space placebo tests are carried out for all specifications. The results of these placebo tests show that the found treatment effects are not statistically significant. They are too small and/or partly driven by chance. For the carbonates and juice consumption specification, robustness checks are performed. Each country soda consumption predictor and country in the synthetic control are iteratively removed from the sample to check the robustness of the results towards the included predictors and donor pool countries. The robustness checks show that the results are fairly robust.

The remainder of this paper will have the following structure. First of all, the French soda tax will be elaborated on. Then, a theoretical framework of soda taxes will be established, followed by the existing empirical studies on the effects of the French soda tax. Thereafter, the data and empirical estimation strategy are set out, followed by the results. Subsequently the robustness and limitations of the results will be discussed, and lastly a conclusion will end this paper.

## Background of the French soda tax

In August 2011, the France Constitutional Council approved a law that instituted a lump-sum tax of €7.16 per hectolitre (7.16 Eurocents per litre) on sweetened drinks levied on suppliers. The amount of the tax is adjusted every year with the growth of the consumer price index. Other than that, the tax has not been changed. The law was effectively implemented on the 1st of January 2012. The tax applies to all non-alcoholic sweetened beverages, both sugar-sweetened and artificially sweetened irrespective of the amount. It taxes the amount of liquid and not the amount of sugar or sweetener. The official rationale of the law is raising revenue to reduce national debt (Ecorys, 2014). Throughout the paper this tax is referred to as the 'soda tax'.

The version of the tax described above, is significantly different from earlier drafts of the tax and it emerged out of political compromises. Earlier drafts of the law were not well received by the general population, soda industry, deputies and expert legislators. The main counterarguments were based on the technical complexity and regressiveness of the tax. A series of unexpected events eventually led to the passing of the significantly different final version of the law. The first draft encompassed a tax of 3.58 cents per litre on just sugar-sweetened beverages. Its implementation was supposed to be based on two rationales. The first and main goal of the intervention was to contribute to the reduction of sweetened beverage consumption, as these drinks are unhealthy for citizens. The second rationale, as articulated by the French senate, was based on the idea that consumption of products that lead to negative health externalities, should be taxed to compensate for these costs. As stated above, the final version doubled the excise amount, changed the rationale to revenue-raising and expanded the scope with artificially sweetened beverages. (Ecorys, 2014; Le Bodo, Etilé, Gagnon & De Wals, 2019).

Julia, Méjean, Vicari, Péneau and Hercberg (2015) investigated the acceptance and perceptions of the French soda tax nine months after its introduction. They did this by analysing a representative sample of the French population consisting of 2000 surveyed individuals. In general, the tax was supported by almost half of the participants. Interestingly, a larger proportion of participants (57%) supports a tax on all foods and beverages that are bad for health. Conditional on sub-criteria more French inhabitants are supportive of a soda tax. 73 percent supports a soda tax if the generated revenue is used to improve the healthcare system. 72 percent supports a soda tax if prices if other (healthy) foods and beverages go down. Also, more than half believe that the soda tax could help improve the health of the population. Individuals with lower education and younger individuals were more likely to be opposed to the soda tax.

## Literature

*Soda taxes in general*

The markets for sin goods like tobacco, alcohol, fast food and sugary drinks are characterized by the presence of negative externalities and internalities. These goods tend to be overconsumed and -produced from the perspective of social welfare. The economic rationale for soda taxes relies on the Pigouvian notion of government intervention by taxation, to offset any negative externalities and internalities that are present in the soda market.

Some individuals may not consider costs on society, externality costs, when making their soda consumption decision. Contrary to the consumption of soda, other sin goods may generate a direct externality to the environment. Cigarette consumption generates for example the direct hazard of second-hand smoking. In the present case of the soda market the externality costs mainly consist of costs that are the result of excessive soda consumption and subsequent health problems. These health costs become a burden on society through (mandatory) health insurances, which are a result of pre-existing asymmetric information problems in the second-best world (Allcott, Lockwood & Taubinsky, 2019a; World Bank, 2020). Besides these healthcare costs, obesity is connected to other economic costs with possibly an even larger burden on society. Examples are reduced labor supply, productivity, human capital and tax revenues (Lehnert et al., 2013; Nikolic, Stanciole & Zaydman, 2011). The global economic cost of obesity is currently estimated at $2 trillion dollars per year (Swinburn et al., 2019). It is important to note that externalities are not equal to all economic costs of soda consumption. When an individual takes into account that consuming a can of soda has certain costs, purchasing cost and all other costs, but still consumes the can of soda by considering that the benefits of consuming outweigh these costs, there is no problem in terms of social welfare. This consumption creates a surplus of utility. The problem only arises when not all costs are internalised in the consumption decision and there is a deficiency of utility (Allcott, Lockwood & Taubinsky, 2019a).

In the soda market, some individuals may underestimate the costs and/or overestimate the benefits to themselves when choosing to consume sugary drinks. These internalities can for example arise when consumers are unable to sufficiently take the adverse long-term health effects of soda consumption into account when making their soda consumption decisions. This can lead to an overconsumption of sugary drinks from the perspective of the consumer itself. Whether an individual is able to make efficient consumption decisions is mainly driven by the information that the person has access to and its ability to put the information to good use. Several behavioral biases like self-control bias and/or present bias may interfere with this. Especially children and young adults are prone to these biases and underestimate the perceived costs of soda consumption and overestimate the perceived benefits of soda consumption. Soda marketing campaigns are very good at exploiting these behavioural biases. Also for internalities holds that no problem arises when a consumer takes all costs to itself into account. There is only a problem when not all costs are internalised in the consumption decision and there is a deficiency of experienced utility. (Allcott, Lockwood & Taubinsky, 2019a; Brownell et al., 2009; World Bank, 2020). It should be noted in this context that, (sin) taxes which are advocated to offset internality costs are not uncontroversial. Many consider this a kind of paternalism that is ethically undesirable. Paternalistic interventions force or manipulate consumers to change their behaviour, for their own good. Paternalists argue that these consumers know themselves (afterwards), that the change of behaviour better represents their real preferences, but they cannot implement the change themselves. They need help from the government (Whitman, 2006).

A soda tax is able to generate benefits in four different ways. First of all, it could directly reduce consumption by raising the price of the taxed good. This is desirable given the presence of externalities and internalities in the market. It holds in most cases that raising the price of a good, reduces demand for that good. The scale of the demand reaction however, depends on the size and incidence or pass-through rate of the tax. In a perfectly competitive market, the tax pass-through rate depends on the demand and supply elasticities of the relevant markets. The higher the elasticity of supply and the lower the elasticity of demand, the larger the pass-through of the tax to prices is. In markets that are not perfectly competitive, the pass-through rate is not so simple to determine. It depends on the specific demand characteristics and production costs in the market (Berardi et al., 2016). It should also be taken into account that the fallen demand for the taxed good may raise the demand for substitutes. The substitution effect occurs towards untaxed substitutes. In the present case, these substitutes include other beverages like water and alcoholic beverages, but also sodas across the border in a country without a soda tax (Cawley, Thow, Wen & Frisvold, 2019). So cross-border substitution could take place in Spain, Switzerland, Italy and Germany. Substitution towards buying soda in Belgium was possible until 2016, when they introduced their own soda tax (UNC, 2020).

Second, a soda tax and its subsequent (social) media attention can raise awareness of the health risks of consuming sugary drinks. This is also called the signalling effect of a tax. The relative marginal willingness to pay of consumers is changed, which complements the price effect in reducing demand. This phenomenon occurred in Berkeley (California). The mere announcement of a soda tax in the city dropped purchase amounts of soda on the University of California campus, relative to control beverages. This reduction took place months before the actual introduction of the tax (Taylor, Kaplan, Villas-Boas and Jung, 2019).

A third way in which a soda tax can be beneficial is by raising government revenue (World Bank, 2020). The earned revenue could for example be used to reduce distortionary taxation in other markets. In the case of the French soda tax the predicted tax revenue was €280 million per year. The actual revenue was €375 million in 2013 (Ecorys, 2014). More recent estimates do not exist or are not publicly available.

Last of all, a soda tax could have distributional effects that may be considered as a cost or benefit depending on political equity preferences. It is established in the literature that poorer consumers have a higher intake of sugary drinks. This means that they will also pay a higher amount of tax, especially relative to their income. So, in principle a soda tax can be regarded as financially regressive. However, the tax will also have more benefits for poor people, considering that more internality costs are internalised by the tax compared to consumers with a higher income. So, the higher tax burden may be offset partially or more than fully by health benefits. Consequently, the burden of the tax does not necessarily fall heavier on poor consumers (Allcott, Lockwood and Taubinsky, 2019a).

Allcott, Lockwood and Taubinsky (2019b) investigate the trade-off between corrective consumption effects (externalities and internalities) and redistributive effects of sin taxes, given the market conditions, to derive the optimal sin tax formula. In contrast to earlier optimal tax derivations, the authors take the presence of non-linear income taxation and heterogeneity of preferences into account. They set the goal to express the formula as a function of parameters that can easily be empirically measured. Under optimal income taxation the authors found the optimal sin tax to be as in equation 1. This can be rewritten to equation 2 for the purpose of interpretation.

$$t \approx \frac{\bar{y}(1+\sigma)+e-\frac{p}{\bar{s}\bar{\vartheta}c}Cov\left[g(z),s_{pref}(z)\right]}{1+\frac{1}{\bar{s}\bar{\vartheta}c}Cov\left[g(z),s_{pref}(z)\right]} \tag{1}$$

$$t \approx \bar{y}(1+\sigma)+e+\frac{1}{\frac{d\bar{s}}{dt}}Cov\left[g(z),s_{pref}(z)\right] \tag{2}$$

Where $\bar{y}(1+\sigma)+e$ represents the corrective motive of the tax, consisting of externality $e$ and internality $\bar{y}$. The internality is scaled by $\sigma$ which depicts the relative corrective internality reduction between low- and high-income consumers. Intuitively, internality reductions fall back on the individual, while externality reductions fall back on society. Internalities thus have to be scaled in accordance with social marginal welfare weights. Consumers differ in their ability to generate income, denoted by their type $z$. The covariance between the social marginal welfare weights of persons z and the between income sin-good consumption heterogeneity, $Cov\left[g(z),s_{pref}(z)\right]$, represents the redistributive motive of the tax. So, $s_{pref}(z)$ denotes the heterogeneity of preferences among consumers z that cannot be attributed to income effects.

The covariance thus captures to what extend soda consumption signals consumer ability type z. In other words, this term represents the power of the sin tax to redistribute to the extent that cannot be achieved with the income tax. It is scaled by $1/(ds/dt)$ to establish the relevance of redistribution as compared to correction. The heavier consumers respond to the tax, the less important the redistributive motive becomes, relative to the corrective motive. When the government does not care about redistribution, the optimal tax will simply be a Pigouvian tax, as given in equation 3.

$$t = \bar{y} + e \tag{3}$$

All parameters in the formula are empirically measured for the US soda market in the same paper. This results in an optimal federal level soda tax of 1.42 US Dollar cents per ounce under the existing income tax. This corresponds with $0.48 per litre. Without redistributive motives the optimal soda tax would be 1.78 US Dollar cents per ounce ($0.60 per litre). It is difficult to assess whether the optimal tax amount can be transferred directly to the case in France. Key parameters like the existing income tax, internality costs, externality costs and market characteristics like the consumption amount and elasticities are possibly incompatible. An entire case study could be attributed to this question.

However, in an accompanying article the authors formulate seven important concrete policy suggestions against which the French soda tax can be assessed. They review the existing literature on the background of soda taxes, their optimal tax formula and the literature regarding the parameters of their tax formula. Policy makers should: (1) focus on counteracting externalities and internalities and not on minimising soda consumption, (2) target the people who generate the largest externalities and internalities with their policies, (3) levy a tax on the amount of sugar and not on amount of liquid, (4) only tax sugarless substitutes if they also cause uninternalized health harms, (5) when considering equity effects, also consider health benefits and not just who pays the tax, (6) implement soda taxes at the highest possible level of aggregation and (7) consider that the benefits of a soda tax are probably greater than the costs (Allcott, Lockwood & Taubinsky, 2019a). As is apparent from the prior section about the background of the French soda tax, the tax does not fulfil points 2, 3, 4, 5 of the policy suggestions. The French probably took point 7 into account, otherwise the tax would not have been implemented. Given the statement by the French senate about offsetting externalities, they also took a part of point 1 into account. Internalities where not specifically mentioned. Point 6 speaks for itself, however if possible, a European soda tax could be even more effective. The

French soda tax is therefore not likely to be the optimal tax. This is not surprising, given the political bureaucracy and compromises leading up to its introduction, as described by Le Bodo et al. (2019).

*Empirical analyses of the French soda tax*

The effects of soda taxes around the world have not been analysed extensively, despite their wide-spread introduction in recent years. The effects of the French soda tax on prices, consumption and health have been the subject of a few earlier academic studies. These studies will be discussed in this section.

Capacci et al. (2019) exploit two Italian regions bordering two French regions as a natural control group. They estimate the impact of the soda tax on prices and consumption by comparing the French and Italian regions in a difference-in-difference design. They find that there is a non-significant negative effect on purchases, even though the tax seems to have been fully passed through to retail prices. This could be explained by the relatively small size of the tax. The lower bound pass-through rate is 66% and the upper bound even indicates a pass-through rate of higher than 100%. The Italian regions were however not a good natural control group since they lacked sufficient comparability to the two French regions. This is indicated by a violation of the parallel trends assumption. There were likely time-varying differences between Italy and France that render the estimations biased. Besides, when only comparing bordering regions, cross-border substitution becomes a relatively large factor. This substitution effect will also interfere with the results.

Berardi et al. (2016) also shed a light on the effect of the French soda tax on prices. To construct a sufficiently precise counterfactual the authors use a machine learning adaptation of the synthetic control method that could roughly be described as a double synthetic control method. With this method, statistically optimal control groups for soda, flavoured waters and fruit-flavoured drinks were constructed out of product groups that did not see a tax introduction. They find a full pass-through for sodas, a 94% pass-through for fruit-flavoured drinks and a 62% pass-through for flavoured waters. There is on average no evidence of over-shifting of the tax to consumers. While the method and results of this research seem very promising, there were flaws in the data that was used. The data namely stemmed from a price comparison site that compared online soda prices of supermarket ‘drive-throughs’. It is likely that these online prices are not representative for the full French soda market, giving the research a lack of external validity.

Powell and Chaloupka (2009) reviewed the existing evidence regarding the association between unhealthy food taxes and consumption decision patterns. They found a total of nine relevant studies that empirically analysed the relation between prices and weight outcomes. Most studies did not find a statistically significant effect. When a significant effect was found, the effect was small in magnitude. However, even though the taxes have a small effect on individual behaviour, the aggregate effect could be large when the tax is applied broadly. The weight of children and young adults from low-income families seems to be more sensitive to price changes from taxes and subsidies. The greater effect on the groups may offset some distributional concerns.

So, when judged in the light of the optimal tax formula, the French soda tax cannot be considered optimal. The pass-through rate of the tax is empirically between 62-100% and the tax has a very small amount of €0.07 per litre. Taken together, this raises the expectation that the introduction of the soda tax in France had a very limited causal effect on consumption.

## Data

Time series data on soda consumption and alcohol consumption were obtained for all western countries from the Passport Euromonitor database. This database is operated by Euromonitor International and includes statistical information on over 25 industries for almost all countries in the world. The available information includes market sizes, company market caps, market forecasts, consumer and household level information and more. The measured variables are standardised around the world, which makes the data especially suitable for cross-country comparisons (Passport Euromonitor, 2021). In table A1 a full list of the included countries is reported.

Soda consumption is measured in two different ways. To get a general picture of the effect of the introduction of the French soda tax on soda consumption, the first measure is expenditures per capita on soft drinks. This measure is available from 1995 until 2019 and is defined as the average amount a person spent on bottled water, juices, carbonates, sports and energy drinks and ready-to-drink tea and coffee. As this variable refers to expenditures, the data points are measured in local currencies. To allow for cross-country comparability all values are converted to Euros using year on year exchange rates. This variable also includes potential substitutes of soda that are not taxed, such as water, 100% pure juice and unsweetened juice, which might interfere with the results.

Therefore, to get a more detailed inside into the effects on specific product groups, consumption of soda is measured separately for carbonates and juice. Carbonates consumption includes all sweetened non-alcoholic drinks containing carbon dioxide. Carbonated fruit juices are thus captured by this variable. Juice consumption includes all beverages containing fruits and/or vegetables. This means that pure juices (100% juice), nectars (25-99% juice) and juice drinks (up to 24% juice) are included in this variable. The measures are defined as the average consumption of a person in litres through all distribution channels. These channels would include sales from supermarkets, restaurants, bars, vending machines etcetera. The measures are available from 2006 until 2019. All three measures have their pros and cons, some of which are already mentioned in this section. The strengths and weaknesses of the data will be elaborated on in the discussion section.

To investigate potential substitution effects of the soda tax towards other beverages, data on alcohol expenditures per capita is obtained. The variable is available from 1995 until 2019 and is defined as the average amount a person spent on beer, wine, spirits and other alcoholic drinks. As this variable refers to expenditures, the data points are measured in local currencies. To allow for cross-country comparability all values are converted to Euro's using year on year exchange rates.

From the Our World in Data database several country characteristics relating to soda consumption are selected for the pre-intervention period. The reason why these predictors are selected, is discussed in the following methodology section. These include GDP per capita, percentage of population aged 15 till 24, overweight rate, tertiary education rate and the urban population rate. GDP per capita is an indicator of the welfare in a country and is measured in constant international US dollars (Roser, 2019). The percentage of the population aged 15 till 24 is simply calculated as the number of people in a country aged 15 till 24 divided by the total population (Ritchie & Roser, 2019a). The overweight rate is calculated as the number of individuals in a country with a body mass index (BMI) greater than 25 divided by the total population. The BMI of a person is used to determine whether this person has a healthy weight. It is calculated as a person's weight in kg divided by the squared height in meters (Ritchie & Roser, 2017). The tertiary education rate is measured as the percentage of the population above 15 years old that has completed tertiary education. This variable is only measured once every five years, because of data restrictions (Ortiz-Ospina & Roser, 2013). The urban population rate is measured as the share of the population in a country that lives in urban areas, urban population divided by the total population (Ritchie & Roser, 2019b). All aforementioned data from the various sources is merged into one dataset and used in this study. Table 1 reports descriptive statistics for the full sample.

Table 1 Descriptive statistics

| Variable | Obs. | Mean | Std. deviation | Min | Max |
|---|---|---|---|---|---|
| Soda expenditures (€) | 744 | 108.15 | 58.89 | 5.00 | 322.40 |
| Alcohol expenditures (€) | 744 | 274.06 | 169.48 | 27.1 | 1024.20 |
| Juice consumption (L) | 434 | 27.65 | 10.95 | 10.00 | 62.80 |
| Carbonates consumption (L) | 434 | 67.18 | 27.84 | 21.10 | 184.80 |
| GDP per capita ($) | 496 | 31444 | 12406 | 7386 | 65083 |
| Aged 15-24 | 496 | 0.134 | 0.016 | 0.099 | 0.185 |
| Overweight | 496 | 0.565 | 0.039 | 0.468 | 0.675 |
| Urban population | 496 | 0.713 | 0.118 | 0.506 | 0.977 |
| Tertiary education | 93 | 0.123 | 0.051 | 0.030 | 0.268 |

Notes: This table reports descriptive statistics for the full sample of countries listed in table A1. Soda expenditures and alcohol expenditures are reported for the 1995-2019 period. Juice consumption and carbonates consumption are reported for the 2006-2019 period. GDP per capita, aged 15 till 24, overweight rate, tertiary education and urban population are reported for the 1995-2011 period. Tertiary education is only measured every five years, starting in 1995. Soda expenditures and alcohol expenditures are in euro's. Juice and carbonates consumption are measured in litres. GDP is in constant international US dollars. Aged 15-24, Overweight, Urban population and Tertiary education are measured as the fraction of the total population. The data is merged from several databases.

## Methodology

*Synthetic control*

The synthetic control method, inspired by Abadie, Diamond and Hainmueller (2010), will be applied to estimate the counterfactual soda expenditures, carbonates consumption, juice consumption and alcohol expenditures trends. With this method, any weighted average of non-exposed countries is considered as a potential control. A synthetic France is constructed based on other western countries that did not implement a soda tax. This synthetic control then serves as the counterfactual. Or in other words, the post-intervention trend of the synthetic France represents the soda consumption trend of France in the case where the soda tax would not have been implemented. By applying this particular method, a more appropriate counterfactual is estimated than any single country could be. There is a formal selection of the counterfactual based on a data-driven procedure.

Denmark and Finland have had a sugary drink tax since as far back as the 1930's. In 2011 Hungary passed a law that instituted a tax on all products with proven health risks, including sugary drinks. Latvia is another country that has had a sugar tax relatively long, since 2004 (Ecorys, 2014; UNC, 2020). Because these countries will interfere significantly with the results, they are excluded from the synthetic control. The United Kingdom introduced a two-tiered sugar tax in 2018. The tax is called two-tiered because it consists of two different tax rates for different levels of sugar content in the beverage. The tax rate is 18 pence per litre for sugar sweetened beverages with 5-8 grams added sugar per 100 millilitre and 24 pence per litre for sugar sweetened beverages with more than 8 grams added sugar per 100 millilitres. Other countries in the sample with this two-tier design are Ireland and Norway. Both also instituted in 2018 (Backholer, Vandevijvere, Blake & Tseng, 2018). Portugal introduced a soda tax in 2017 and Belgium in 2016 (UNC, 2020). Since these countries introduced the tax relatively recently, they don't interfere with the selection of the synthetic control. Including them might even make the synthetic control more accurate, since these countries are likely similar to France. These countries will therefore be considered for the synthetic control. The treatment effects for the year 2016 and later might however be 'contaminated', when countries with a recent soda tax are included in the synthetic control. This results in a trade-off that will be analysed for the present case in the discussion section.

To select the synthetic control a wide variety of pre-intervention country characteristics that have predictive power for soda consumption can be used. In this case GDP per capita, percentage of population aged 15 till 24, overweight rate, tertiary education rate, urban population rate and lags of soda consumption are used. The youth population in a country is a good predicter of soda consumption, since children and young adults drink more sugary drinks compared to the older population of a country. The same holds for low-income versus high-income groups and low-educated versus higher-educated groups (CDC, 2021; Zagorsky & Smith, 2020). Higher soda consumption is associated with other unhealthy eating habits, besides soda consumption and also with living in rural areas (Sharkey, Johnsen & Dean, 2011). Other predictors of soda consumption like prices and household income cannot be used in this design due to data restrictions. These restrictions mainly consist of measurement issues and cross-country comparability issues.

Vector $W = (\omega_2, \dots, \omega_{j+1})$ of synthetic control weights is determined by minimising the root mean squared prediction error (RMSPE). Say $X_1$ represents a vector of the selected pre-intervention characteristics for the treated country. The aim is to match these characteristics as closely as possible by the vector $X_0$ of pre-intervention outcomes for the synthetic control. The difference in pre-intervention outcomes between the treated unit and the synthetic control is then given by $X_1 - X_0 W$. Vector $V = (v_1, \ldots, v_m)$ represents the weight attached to each predictor $m$. This allows the method to account for differences in predictive power of each characteristic on the outcome variable. The optimal vector of predictor weights V* and the optimal vector of synthetic country weights W* are chosen as the values that minimize equation 4. The synthetic control weights and predictor weights are each restricted to have a value between 0 and 1 and both add up to a total of 1.

$$RMSPE = \sum_{m=1}^{k} V( X_{1m} - X_{0m} W)^2 \tag{4}$$

The predicted counterfactual outcome in year t, $Y_{1t}^N$, is equal to the weighted sum of post-intervention soda consumption for the control units, as seen in equation 5. Consequently, the treatment effect in year t, $\tau_{1t}$, is equal to the soda consumption for France in year t, minus the counterfactual outcome. This is denoted in equation 6. The weights are determined in the process described above and are thus captured in the vector of synthetic control weights W*. The result is an estimation of the treatment effect for every year after the intervention.

$$Y_{1t}^N = \sum_{j=2}^{J+1} \omega_j Y_{jt} \tag{5}$$

$$\tau_{1t} = Y_{1t} - Y_{1t}^N \tag{6}$$

The estimated treatment effect is an unbiased causal effect when several assumptions hold, as also considered by Abadie (2020). The overarching assumption is that the soda consumption trend of the synthetic control provides an accurate estimation of what would have happened to the soda consumption in France if the soda tax would not have been introduced. There are two sub-assumptions to this main assumption. Firstly, the selection of synthetic control weights should fulfil its objective to make sure that the synthetic and real France are identical or very similar before the intervention. Pre-intervention soda consumption levels of France and the synthetic France should be very close. This is also called the fit of the pre-intervention trend and already indicates that France and the synthetic France are similar in terms of underlying characteristics that predict soda consumption. This similarity should be evidenced by inspecting the balance in pre-intervention outcomes. France and the synthetic France are not as similar as first expected when there is a disbalance between some characteristics. If this first sub-assumption holds, the synthetic France and France were likely similar before the introduction of the soda tax.

Second of all, the synthetic and real France should still be similar or even identical in the post-intervention period, except for the introduction of the soda tax. The first sub-assumption already gives an indication that this is the case. However, spill-over effects and idiosyncratic or asymmetric shocks to soda consumption are a threat to this second sub-assumption. The introduction of a soda tax could incentivise people to buy sweetened beverages across the border in a neighbouring country (Bergman & Hansen, 2010). If one of these neighbouring countries is included in the synthetic control, the counterfactual soda consumption will be overestimated. Which in turn leads to an overestimation of the treatment effect. Idiosyncratic and Asymmetric shocks could for example occur in the form of other measures to discourage soda consumption. When these measures are implemented in countries in the synthetic control and not in France or vice versa, the treatment effect will also be biased. In these cases the counterfactual does not accurately represent the soda consumption trend that would have occurred in France in absence of the soda tax. Whether the assumptions hold in the presented case will be elaborately discussed in the discussion section. It is however per definition impossible to ascertain with full confidence that the counterfactual is accurate in the post-intervention period.

*Placebo tests*

Normally the statistical significance of estimations is judged by assessing p-values. These conventional p-values are generated based on the idea that there is a certain amount of uncertainty regarding the representativeness of the sampling procedure. With the synthetic control method there is no sampling involved. Aggregate data that stems from the entire population is used. This makes classical inference impossible (Abadie, 2020). So, as proposed by Abadie (2020), placebo tests are performed to gain inside into significance of the results. With these tests the intervention is applied to cases where the intervention did not take place. The validity of the results is severely weakened when this placebo effect is equal to or larger than the treatment effect that was found.

In this case two types of placebo tests will be executed. The first one is generally referred to as an in-time placebo test. The introduction of the soda tax in France is pre-dated to an earlier year. When there is a sizable effect found for this intervention, while there was of course no introduction of a tax that year, this can be considered as an issue. It is an indication that the treatment effects found for the real intervention cannot be attributed to the introduction of the soda tax. The placebo test suggests in this case that the synthetic control does not approximate the French soda consumption trend well. The second type of placebo test is generally referred to as an in-space placebo test. The introduction of a soda tax is assigned to other countries in the donor pool. When this results in a sizeable effect, this is regarded as an issue, since there was of course no introduction of a soda tax in that country. This test can be applied to all potential control countries in the donor pool for every post-intervention year. This results in a distribution of placebo effects, to which the estimated treatment effects for France can be compared. Standardised p-values can then be determined by estimating the fraction of placebo effects equal to or larger than the effect for the treatment country France. The treatment effect is significant when it is extreme relative to the placebo distribution. The standardised p-values can be compared to the conventional confidence levels, 1%, 5% and 10%.

*Robustness checks*

There will be two robustness checks executed for both the carbonates consumption and juice consumption specifications. The first robustness check entails iteratively removing each country in the synthetic control from the sample. With this country removed, the entire procedure will be executed again. This check assesses whether the results heavily depend on the included countries. The second robustness check entails iteratively removing each chosen pre-intervention characteristic from the method. Since the selection of soda consumption predictors is somewhat arbitrary, it is important that the results are robust toward excluding these predictors.

## Results

*Soda expenditures*

The calculated synthetic control country weights for the soda expenditures specification are reported in column 2 of table A1. For this specification the synthetic control consists of Switzerland, Czech Republic, Croatia, Belgium, Norway, New Zealand and Australia with weights 0.259, 0.259, 0.199, 0.130, 0.070, 0.063 and 0.019 respectively. This means that Switzerland and Czech Republic are given the most weight. All other countries in the donor pool are assigned a weight of zero. Table 2 reports the means for the used soda consumption predictors for the pre-intervention period. Column 2 reports the real France, column 3 reports the synthetic France and column 4 reports the average for the entire donor pool. By comparing column 2 and 4 it becomes clear that the average of all possible control countries does not provide a good counterfactual. There is a lack of similarity, especially with regard to the GDP per capita and the used soda consumption lags. In contrast to the entire donor pool, the synthetic control is able to match the values of the real France more closely. Column 5 of Table 2 reports the optimized predictor weights V. It is clear that the soda expenditures lags have considerably more predictive power compared to the other predictors. In Figure 3 the soda expenditures trends for both the real and synthetic France are displayed from 1995 until 2019. The trends before the vertical line in this graph confirms that the synthetic control tracks the pre-intervention soda expenditures trend of France closely. However, the trends do not notably diverge after the intervention, which already indicates that there is a very small treatment effect.

The treatment effects for every post-intervention year are reported in column 2 of table 3. The treatment effects are simply calculated by subtracting the soda expenditures per capita for the synthetic France from the soda expenditures per capita level for the real France for every year after the introduction of the soda tax. Or in terms of the trends displayed in figure 3, the difference between the solid and dashed line. The effects are both positive and negative, ranging from €5.63 more spending on soda per capita in 2013 to €2.13 less spending on soda in 2015. There is no obvious unambiguous effect of the introduction of the soda tax in France on soda expenditures.

Table 2 Predictor means for soda expenditures specification

| | **France** | | | |
|---|---|---|---|---|
| Predictor | Real | Synthetic | Average of 26 control countries | Weight |
| GDP | 35153 | 34822 | 31326 | 5.097e-3 |
| Overweight | 0.562 | 0.568 | 0.562 | 6.101e-4 |
| Aged 15-24 | 0.129 | 0.130 | 0.135 | 9.158e-4 |
| Tertiary | 0.087 | 0.105 | 0.118 | 1.466e-3 |
| Urban | 0.767 | 0.739 | 0.704 | 2.188e-3 |
| Soda expenditures 1995 | 73.50 | 73.24 | 65.65 | 0.198 |
| Soda expenditures 2000 | 87.10 | 87.54 | 86.91 | 0.199 |
| Soda expenditures 2005 | 110.70 | 110.47 | 103.12 | 0.430 |
| Soda expenditures 2011 | 139.40 | 138.79 | 124.03 | 0.162 |

Notes: The predictor means for the pre-intervention period 1995-2011 are reported in this table for the soda expenditures specification of the synthetic control model. Column 2 reports the actual values for France, column 3 reports the values for the synthetic France and column 4 reports the averages for the donor pool. Column 5 reports the optimized relative predictor weights V. Soda expenditures is measured in euro's. GDP is measured in constant international US dollars. Aged 15-24, Overweight, Urban population and Tertiary education are measured as a fraction of the total population. The data is merged from several databases.

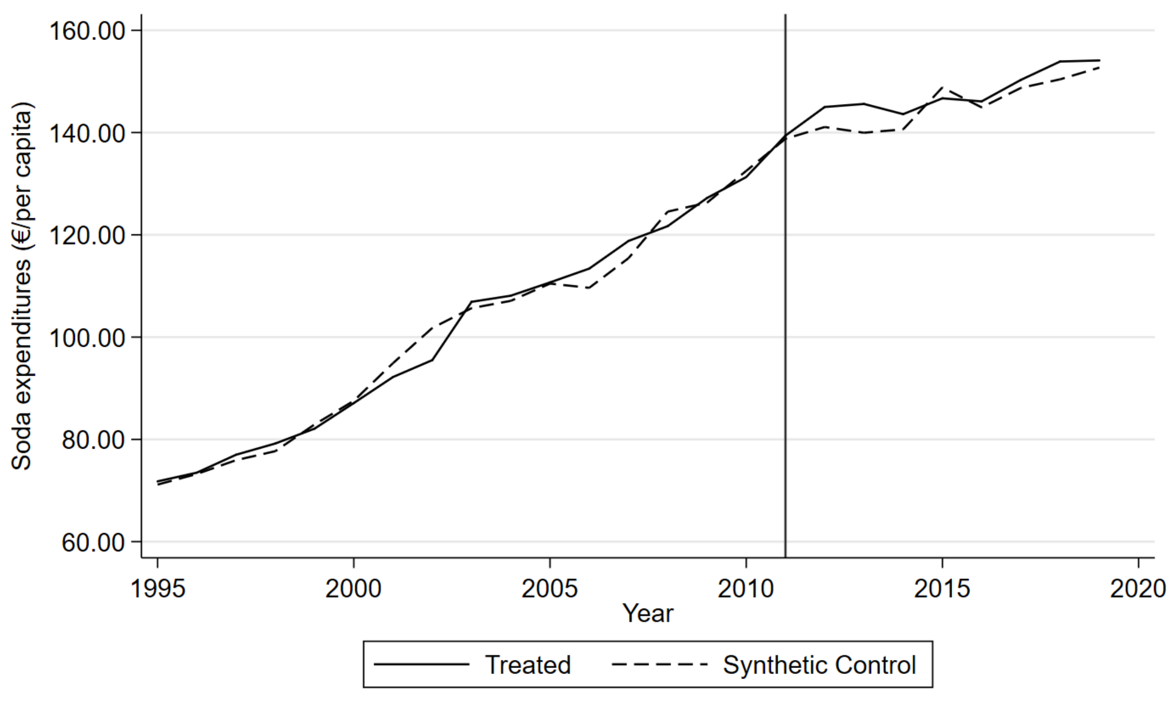


Figure 3 Soda expenditures trend for the real and synthetic France from 1995-2019

Notes: In this figure the trend of soda expenditures is shown for the real and synthetic France from 1995-2019. With the expenditures in Euro's per capita on the y-axis and the year on the x-axis. The solid line represents the real France and the dashed line represents the synthetic France. The vertical line represents the division between the pre- and post-intervention period. The data was obtained from the Passport Euromonitor database.

Table 3 Treatment effects for all specifications

| Year | Soda expenditures | Carbonates consumption | Juice consumption | Alcohol expenditures |
|---|---|---|---|---|
| 2012 | 3.92<br>(0.385) | -1.88<br>(0.308) | 0.75<br>(0.346) | -12.52<br>(0.192) |
| 2013 | 5.63<br>(0.154) | -4.55<br>(0.192) | 1.18<br>(0.308) | 10.67<br>(0.269) |
| 2014 | 2.98<br>(0.462) | -6.07<br>(0.115) | 1.09<br>(0.308) | 13.09<br>(0.308) |
| 2015 | -2.13<br>(0.731) | -6.87<br>(0.192) | 2.21<br>(0.231) | -9.47<br>(0.577) |
| 2016 | 1.18<br>(0.923) | -7.54<br>(0.154) | 4.17<br>(0.192) | 2.57<br>(0.923) |

| | | | | |
|---|---|---|---|---|
| 2017 | 1.56<br>(0.885) | -9.46<br>(0.154) | 5.68<br>(0.115) | 9.71<br>(0.654) |
| 2018 | 3.49<br>(0.615) | -12.61<br>(0.154) | 5.78<br>(0.115) | 14.52<br>(0.462) |
| 2019 | 1.40<br>(0.808) | -14.08<br>(0.154) | 4.70<br>(0.192) | 10.06<br>(0.731) |

Notes: In this table the treatment effect is reported for every post-intervention year. Column 2 reports the treatment effects for the soda expenditures specification in Euro's per capita. Column 3 reports the treatment effects for the carbonates consumption specification in litres per capita. Column 4 reports the treatment effects for the juice consumption specification in litres per capita. Column 5 reports the treatment effects for the alcohol expenditures specification in litres per capita. The corresponding standardised p-values are reported between brackets. These p-values are calculated using in-space placebo tests, as discussed in the methodology section. * p<0.1 ** p<0.05 *** p<0.01.

*Carbonates consumption*

In column 3 of table A1, the calculated synthetic control country weights for the carbonates consumption specification are reported. For this specification the synthetic control consists of Lithuania, Germany, Italy, Lithuania and Sweden, with weights 0.633, 0.271, 0.076 and 0.019 respectively. Lithuania thus represents a large part of the computed statistically optimal counterfactual. In table 4 the predictor means are reported. Also for this specification it is clear that the average of the donor pool does not provide an accurate counterfactual in its entirety. Again, the GDP per capita, tertiary education rate and the chosen carbonates consumption lags do not match. However, in this case the synthetic control also fails to match the GDP per capita and tertiary education rates of the real France closely. This is an indication that the synthetic control does not approximate the true counterfactual well. Column 5 of Table 4 reports the optimized predictor weights V. Similar to the previous specification, the carbonates consumption lags have far greater predictive power than the other predictors. Figure 4 reports the carbonates consumption trends for both the real and synthetic France from 2006 until 2019. Despite the differences in some predictors, the synthetic control does match the carbonates consumption trend of France. The lines start diverging after the intervention, indicating that there is a treatment effect.

The treatment effects for this specification are reported in column 3 of table 3. The introduction of the soda tax in France had a negative effect on carbonates consumption. With an initial reduction in consumption of 1.88 litre per capita that grows steadily over the years to an eventual reduction in soda consumption of as large as 14.08 litre per capita by 2019. This is a sizable decrease of roughly 30% in eight years, considering the baseline soda consumption of 47.40 litre per capita in 2011. These results are also clearly visible in figure 4. The solid and dashed lines start diverging right after the introduction of the soda tax.

Table 4 Predictor means for carbonates consumption specification

| Predictor | France: Real | France: Synthetic | Average of 26 control countries | Weight |
|---|---|---|---|---|
| GDP | 37185 | 28389 | 34934 | 1.633e-4 |
| Overweight | 0.593 | 0.594 | 0.593 | 1.394e-4 |
| Aged 15-24 | 0.125 | 0.134 | 0.129 | 1.135e-5 |
| Tertiary | 0.106 | 0.142 | 0.145 | 5.578 e-6 |
| Urban | 0.780 | 0.698 | 0.712 | 5.565e-5 |
| Carbonates consumption 2006 | 44.70 | 44.08 | 75.32 | 0.284 |
| Carbonates consumption 2008 | 44.90 | 45.81 | 75.28 | 0.380 |
| Carbonates consumption 2011 | 47.40 | 46.77 | 70.91 | 0.335 |

Notes: The predictor means for the pre-intervention period 2006-2011 are reported in this table for the carbonates consumption specification of the synthetic control model. Column 2 reports the actual values for France, column 3 reports the values for the synthetic France and column 4 reports the averages for the donor pool. Column 5 reports the optimized relative predictor weights V. Carbonates consumption is measured in litres. GDP is in constant international US dollars. Aged 15-24, Overweight, Urban population and Tertiary education are measured as a fraction of the total population. The data is merged from several databases.

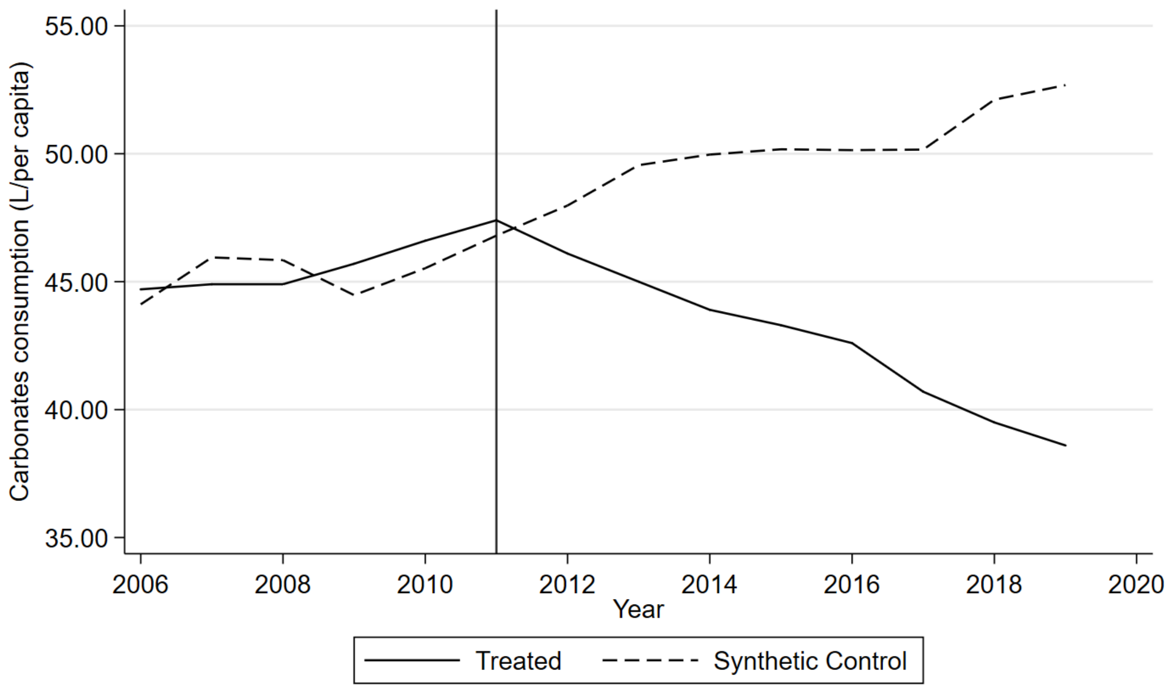


Figure 4 Carbonates consumption trend for the real and synthetic France from 2006-2019

Notes: In this figure the trend of carbonates consumption is shown for the real and synthetic France from 2006-2019. With the consumption in litres per capita on the y-axis and the year on the x-axis. The solid line represents the real France and the dashed line represents the synthetic France. The vertical line represents the division between the pre- and post-intervention period. The data was obtained from the Passport Euromonitor database.

*Juice consumption*

The calculated synthetic control country weights for the juice consumption specification are reported in column 4 of table A1. For this specification the synthetic control consists of The Netherlands, Portugal, New Zealand, Germany, Czech Republic, Canada and Sweden with weights 0.406, 0.275, 0.168, 0.067, 0.029, 0.053 and 0.002 respectively. Table 5 reports the predictor means for this specification. The table shows that, like the other specifications, the entire donor pool does not provide an accurate counterfactual. The selected counterfactual, on the other hand, does match the predictor variable values very closely, and for some predictors even precisely. The amount of juice consumption in 2008 and 2011 is exactly the same in the real and synthetic France. This is also evident in figure 5, where the juice consumption trends for the real and synthetic France are displayed for the 2006-2019 period. The trends start to separate after the introduction of the soda tax. Surprisingly, the trend of the synthetic France takes on a steeper slope than the trend of the real France. This indicates that the introduction of the French soda tax had positive effect on juice consumption. The treatment effects for this specification are reported in column 4 of table 3. The initial effect was an increase of juice consumption of 0.75 litre per capita in 2012. The effect reached its peak in 2018 with an increased juice consumption of 5.78 litres per capita.

Table 5 Predictor means for juice consumption specification

| | **France** | | | |
|---|---|---|---|---|
| Predictor | Real | Synthetic | Average of 26 control countries | Weight |
| GDP | 37185 | 37308 | 34934 | 8.289e-4 |
| Overweight | 0.593 | 0.593 | 0.593 | 7.450e-4 |
| Aged 15-24 | 0.125 | 0.124 | 0.129 | 4.442e-4 |
| Tertiary | 0.106 | 0.122 | 0.145 | 3.442e-4 |
| Urban | 0.780 | 0.775 | 0.712 | 7.859e-4 |
| Juice consumption 2006 | 33.30 | 33.29 | 30.19 | 0.265 |
| Juice consumption 2008 | 34.40 | 34.40 | 30.85 | 0.491 |

| | | | | |
|---|---|---|---|---|
| Juice consumption 2011 | 34.60 | 34.60 | 28.34 | 0.240 |

Notes: The predictor means for the pre-intervention period 2006-2011 are reported in this table for the juice consumption specification of the synthetic control model. Column 2 reports the actual values for France, column 3 reports the values for the synthetic France and column 4 reports the averages for the donor pool. Column 5 reports the optimized relative predictor weights V. Juice consumption is measured in litres. GDP is in constant international US dollars. Aged 15-24, Overweight, Urban population and Tertiary education are measured as a fraction of the total population. The data is merged from several databases.

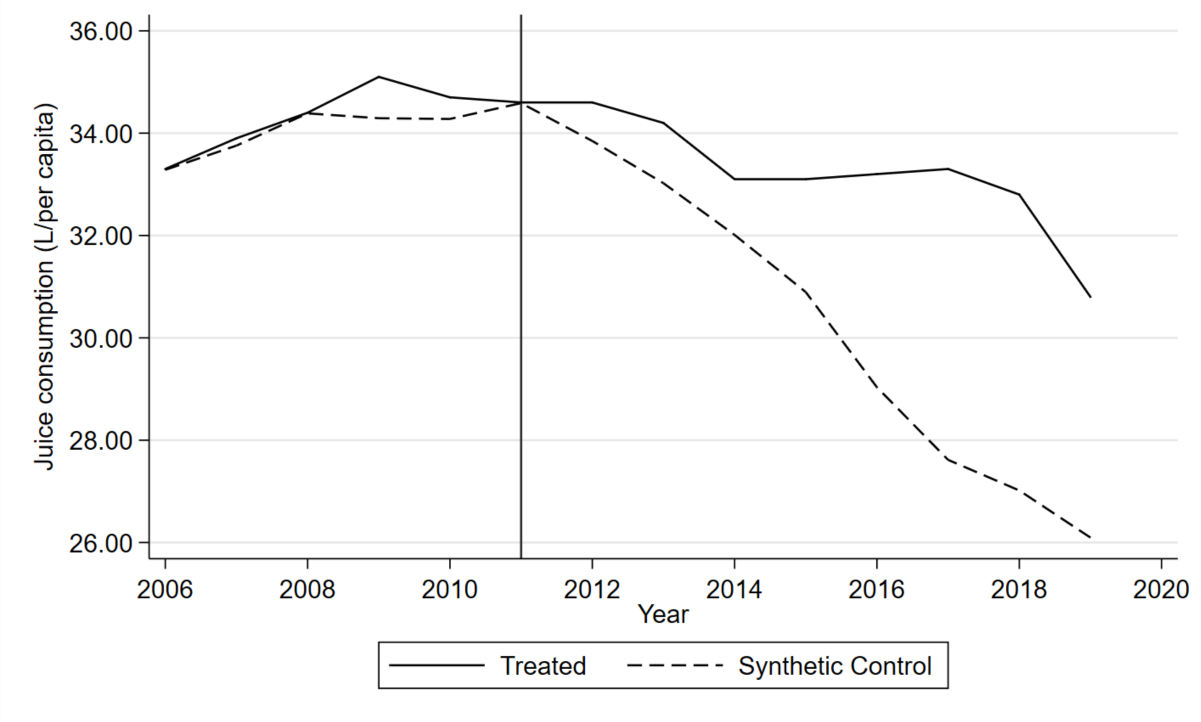


Figure 5 Juice consumption trend for the real and synthetic France from 2006-2019

Notes: In this figure the trend of juice consumption is shown for the real and synthetic France from 2006-2019. With the consumption in litres per capita on the y-axis and the year on the x-axis. The solid line represents the real France and the dashed line represents the synthetic France. The vertical line represents the division between the pre- and post-intervention period. The data was obtained from the Passport Euromonitor database.

*Alcohol expenditures*

The calculated synthetic control country weights for the alcohol expenditures specification are reported in column 5 of table A1. For this specification the synthetic control consists of Germany, Italy, Switzerland, Poland, Ireland, Belgium, Portugal and The United Kingdom with weights 0.295, 0.251, 0.138, 0.086, 0.082, 0.053, 0.049 and 0.046 respectively. In table 6 the predictor means are reported. Once again it becomes clear that the synthetic control is able to match the values better than the average of the entire donor pool. However, the overweight rate is more similar on average in the entire donor pool than in the synthetic control. The superiority of the synthetic control is most notable for the alcohol expenditures lags. This is evidenced by figure 6, where the pre-intervention synthetic alcohol expenditures trend resembles the alcohol expenditures trend of France. The trends do not diverge in the post-intervention period. There is no unambiguous treatment effect. The treatment effects for every post-intervention year are reported in column 5 of table 3. The effects are both positive and negative, and range from €12.52 less spending on alcohol per capita in 2013 to €14.52 more spending on soda in 2018. Column 5 of Table 6 reports the optimized predictor weights V. As was the case with all three previous specifications, the lags of the outcome variable are substantially better at providing a good counterfactual than the other predictors. Thus these lags are given higher weights.

Table 6 Predictor means for the alcohol expenditures specification

| | **France** | | | |
|---|---|---|---|---|
| Predictor | Real | Synthetic | Average of 26 control countries | Weight |
| GDP | 35153 | 36924 | 31326 | 7.532e-4 |
| Overweight | 0.562 | 0.556 | 0.562 | 1.990e-3 |
| Aged 15-24 | 0.129 | 0.124 | 0.135 | 9.942e-4 |
| Tertiary | 0.087 | 0.103 | 0.118 | 4.714e-4 |
| Urban | 0.767 | 0.712 | 0.704 | 7.376e-4 |
| Alcohol expenditures 1995 | 246.5 | 244.9 | 159.3 | 0.246 |
| Alcohol expenditures 2000 | 269.4 | 269.5 | 208.8 | 0.225 |
| Alcohol expenditures 2005 | 281.1 | 280.0 | 242.4 | 0.305 |
| Alcohol expenditures 2011 | 316.7 | 319.9 | 298.8 | 0.218 |

Notes: The predictor means for the pre-intervention period 1995-2011 are reported in this table for the alcohol expenditures specification of the synthetic control model. Column 2 reports the actual values for France, column 3 reports the values for the synthetic France and column 4 reports the averages for the donor pool. Column 5 reports the optimized relative predictor weights V. Soda expenditures is measured in euro's. GDP is measured in constant international US dollars. Aged 15-24, Overweight, Urban population and Tertiary education is measured as a fraction of the total population. The data is merged from several databases.

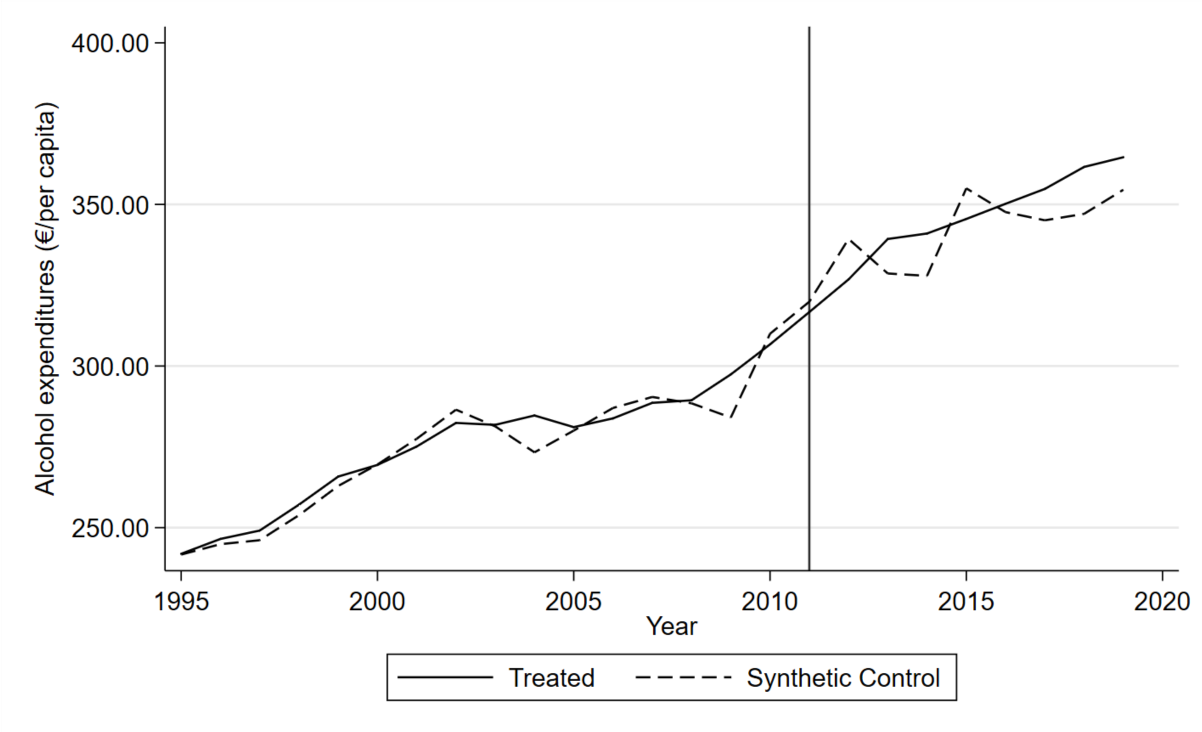


Figure 6 Alcohol expenditures trend for the real and synthetic France from 1995-2019

Notes: In this figure the trend of alcohol expenditures is shown for the real and synthetic France from 1995-2019. With the expenditures in Euro's per capita on the y-axis and the year on the x-axis. The solid line represents the real France and the dashed line represents the synthetic France. The vertical line represents the division between the pre- and post-intervention period. The data was obtained from the Passport Euromonitor database.

## Placebo tests

*In-time placebo tests*

Figure 7 reports the results of the performed in-time placebo tests for all four specifications. The test is simply performed by artificially pre-dating the introduction of the soda tax. Of course, there was no introduction of a tax in that year. So when there is an effect found in the years between the introduction of the artificial and 'real' soda tax, the treatment effects of the 'real' soda tax cannot be attributed to this tax. It is evidence against the finding of a causal effect. In figure 7 it is clearly visible that the trends of the real and synthetic France already start to diverge before the actual tax was implemented for all specifications. If the synthetic control would accurately describe how the French soda consumption would have developed in absence of a soda tax, this would not happen. This result is an indication that the found treatment effects in table 3 are not statistically meaningful. They could be driven by other factors besides the introduction of the soda tax.

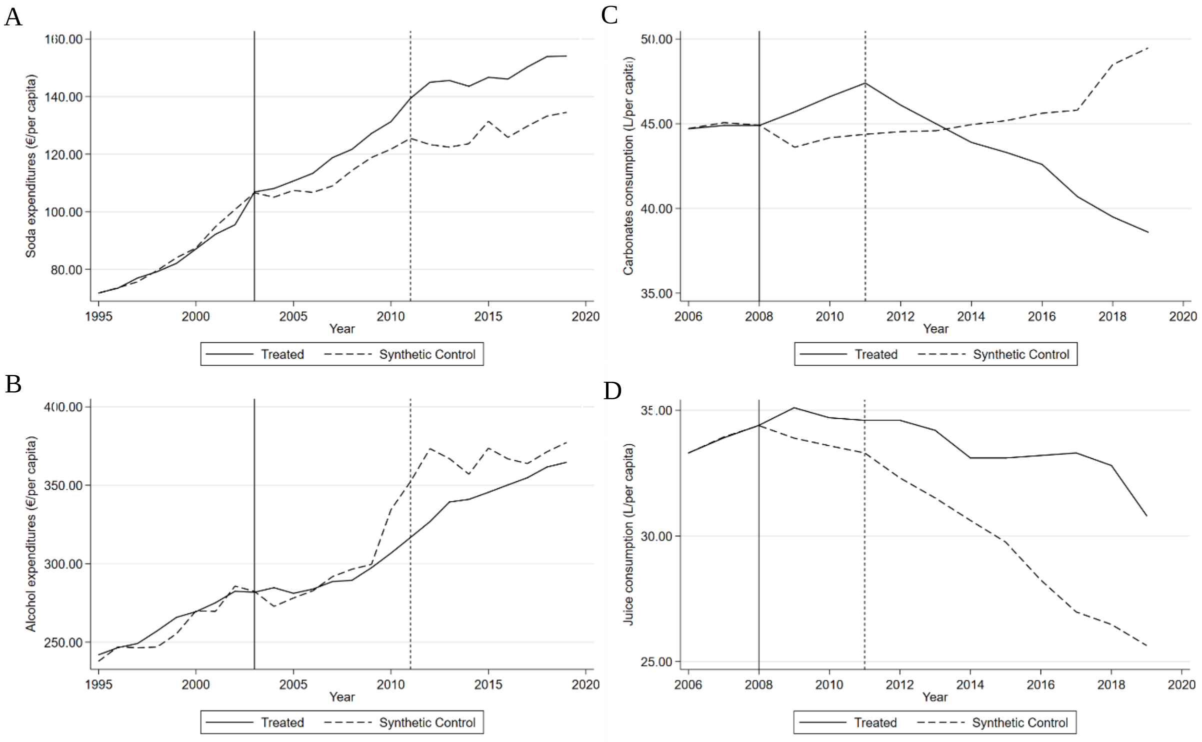


Figure 7 In-time placebo tests for all specifications

Notes: In this figure the results of the performed in-time placebo tests are reported for all specifications. Panel A reports the soda expenditures specification. Panel B reports the alcohol expenditures specification. Panel C reports the carbonates consumption specification. Panel D reports the juice consumption specification. The solid vertical represents the placebo treatment year. The dashed vertical line represents the original treatment year.

### *In-space placebo tests*

The corresponding results of the performed in-space placebo tests to every treatment effect are reported between brackets in table 3. As also stated in the methodology section, these standardised P-values are calculated as the fraction of in-space placebo effects that is equal to or larger than the actual effect. They can be interpreted at the conventional significance threshold. It is useful to note that the standardised P-values are in multiples of 0.038 in this case.[1] So, a P-value of 0.462 means that 12 countries have an equal or larger placebo effect compared to the 'true' treatment effect. The P-values can also be interpreted as the percentage of the 26 countries in the donor pool that have an equal or larger placebo effect.

As seen the table 3, there are no standardised p-values under the 10% threshold in the entire table. For the carbonates consumption and juice consumption specifications there is a minimum

[1] $1/n\ in\ donor\ pool\ = 1/26 = 0.038$

of 3 (p = 0.115) countries with an equal or larger placebo effect for every treatment effect and this amount goes up to 8 countries (p = 0.308) and 9 countries (p = 0.346) respectively. The treatment effects of the soda expenditures and alcohol expenditures specifications have even worse credibility with up to 92.3% of placebo treatment effects larger than the 'true' treatment effect. This is obviously very problematic, since there was no introduction of a soda tax in these countries.

The results of the placebo tests suggest that the found treatment effects are very small and/or at least in part driven by chance. They cannot be attributed to the French soda tax and can therefore not be considered as causal effects of the introduction of the French soda tax on consumption of soda and alcohol.

## Robustness

*Carbonates consumption*

In this section the results of the robustness checks are discussed. Figure 8 reports the results of the robustness checks for the carbonates consumption specification. Panel A shows the result of iteratively removing each soda consumption predictor and lag from the synthetic control method. Removing any of the included soda consumption predictors does not change the results in a troublesome way. Removing the 2008 and 2011 lags however, does alter the synthetic control significantly. Both regarding the pre-intervention fit and the post-intervention carbonates consumption trend. The carbonates consumption specification is thus robust towards excluding soda consumption predictors, but less robust towards excluding soda consumption lags. Panel B shows the result of iteratively removing each country in the synthetic control from the sample. As would be expected, excluding Lithuania has the most influence on the predicted synthetic carbonates consumption trend. This holds especially in the post-intervention period. The results of the robustness tests suggest that the found treatment effects for the carbonates consumption specification are, at least in part, driven by the selected soda consumption predictors and donor pool countries.

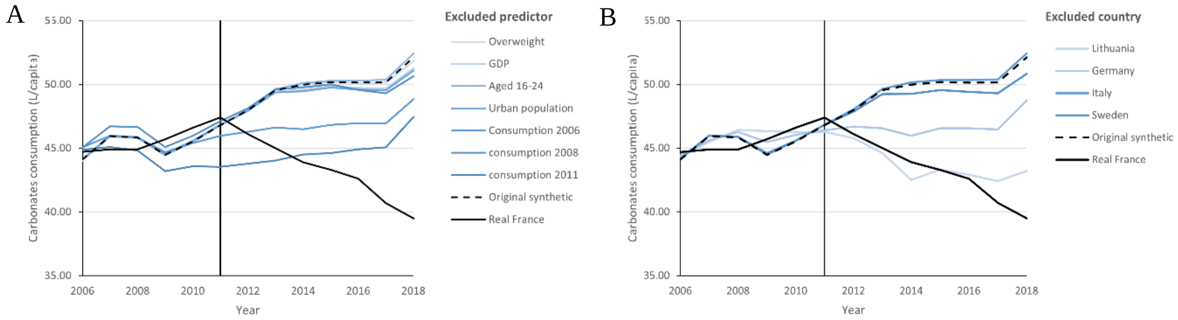


Figure 8 Robustness checks for the carbonates consumption specification

Notes: In this table both robustness checks for the carbonates consumption specification are reported. Panel A reports the synthetic carbonates consumption trends that occurs by iteratively removing one soda consumption predictor. Panel B reports the synthetic carbonates consumption trends that occurs by iteratively removing one of the synthetic control countries from the sample. The real and original synthetic carbonates consumption trends are also reported in both panels.

*Juice consumption*

Figure 9 reports the results of the robustness checks for the juice consumption specification. Panel A shows the result of iteratively removing each soda consumption predictor and lag from the method. Removing any predictor has no significant impact on the resulting counterfactual juice consumption trend. Removing the lags of 2008 and 2011 however, has a considerable influence on the counterfactual trend. Both in the pre-intervention and post-intervention period the trends deviate from the original counterfactual. The counterfactual for the juice consumption specification is robust towards excluding consumption predictors and less robust towards excluding lags. Interestingly, this exact result was also found for the carbonates consumption robustness check. This is no surprise given that the consumption lags have significantly more predictive power, as signalled by their predictor weights V. Panel B reports the result of iteratively removing one synthetic control country from the sample. It is clear that the removal of none of the countries has a significant influence on the counterfactual juice consumption trends. All trends stay close to the original counterfactual in the pre-intervention period, as well as in the post-intervention period.

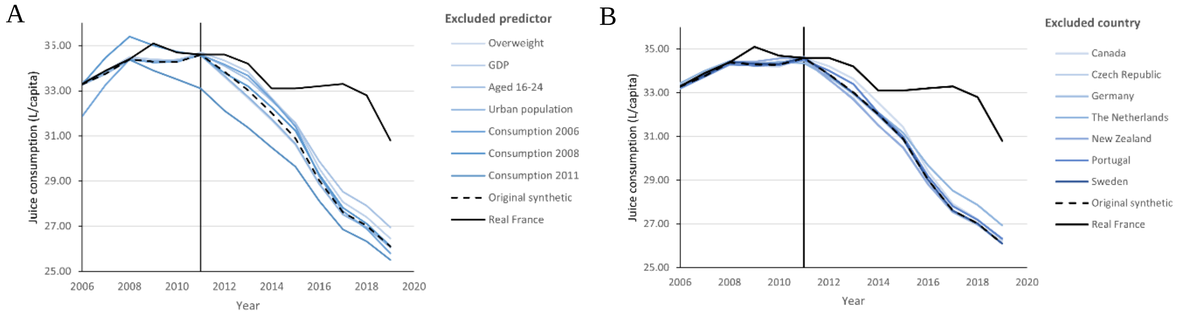


Figure 9 Robustness checks for the juice consumption specification

Notes: In this table both robustness checks for the juice consumption specification are reported. Panel A reports the synthetic juice consumption trends that occurs by iteratively removing one soda consumption predictor. Panel B reports the synthetic juice consumption trends that occurs by iteratively removing one of the synthetic control countries from the sample. The real and original synthetic juice consumption trends are also reported in both panels.

# Discussion

*Results*

It can be concluded from the results section that the effect of the French soda tax on soda expenditures is small and ambiguous. The effect on carbonates consumption is negative and the effect on juice consumption is positive. The juice consumption variable also captures consumption of 100% pure and unsweetened fruit juices (untaxed), besides juices that are sweetened (taxed). It is thus possible that the positive effect on juice consumption stems from a substitution effect away from carbonates and taxed juices towards these untaxed juices. Resulting in a positive effect of the introduction of the French soda tax on juice consumption. The absence of an effect on soda expenditures could be explained by a combination of the negative effect on carbonates consumption and the positive effect on juice consumption. The soda expenditures variable however also includes consumption of bottled water. Substitution towards water consumption may also explains part of the absence of an effect on soda expenditures. The effect on alcohol expenditures is also small and ambiguous. There is no substitution effect towards alcohol.

*Approximation of an accurate counterfactual*

There are however some indications that the found results do not reflect the causal effect of the introduction of the French soda tax on consumption. As stated earlier, the found treatment effects can be considered unbiased when the counterfactual accurately approximates what would have happened to the French consumption trends in absence of the soda tax. This means that the synthetic France should be the same as the real France before the intervention in terms of soda consumption. As well as the same as the real France after the intervention, except for the introduction of a soda tax.

The similarity of the real and synthetic France before the introduction of the soda tax should be evidenced by a close pre-intervention fit of the consumption trends and balance in the consumption predictors. As becomes clear from the results section, the synthetic pre-intervention consumption trend is relatively close to the real consumption trend for all four specifications. Although the synthetic trends do not track the real trends perfectly, this can still be seen as an indication that the real and synthetic Frances are similar pre-intervention. For the soda expenditures, alcohol expenditures and juice consumption specifications the good predictor balance confirms that the real and synthetic Frances are similar before the introduction of the soda tax. The first sub-assumption holds. The predictor balance is however not as strong for the carbonates consumption specification. However, the predictor weights V suggest that the predictors are of marginal meaning as compared to the consumption lags in terms of predictive power. There is therefore a large possibility that the disbalances in the predictors are not problematic in this case, since the consumption trends are similar. The real and synthetic France are likely still sufficiently similar before the intervention in terms of soda consumption.

When the synthetic and real France are similar before the introduction of the tax, it is likely that they are also similar after the introduction. However, the similarity is per definition impossible to test and prove formally. It is nevertheless possible to falsify the assumption by proving the presence of spillover effects and/or idiosyncratic shocks. These occurrences are however difficult to prove and may require an in-depth case study on their own. It can be assumed that the real and synthetic France are similar in terms of consumption after the introduction of the soda tax, unless falsified.

Cross-border substitution or spill-over effects could take place towards Spain, Switzerland, Italy and Germany. Substitution towards buying soda in Belgium was possible until 2016, when they introduced their own soda tax. As shown in table A1, the soda expenditures specification has Switzerland and Belgium (39%) in the synthetic control, carbonates consumption has Italy and Germany (35%) in the synthetic control, juice consumption has Germany in the synthetic control (7%) and the alcohol expenditures specification has Switzerland, Italy, Germany and Belgium (73%) in the synthetic control. Cross-border substitution is thus a possible problem for all specifications, but cannot be proven in this study.

An example of an idiosyncratic shock is the introduction of a soda tax in one of the countries in the synthetic control. Belgium (2016), Portugal (2017), The United Kingdom, Ireland and Norway (2018) are countries that introduced a soda tax in the post-intervention period. Since these countries introduced the tax relatively recently, they don't interfere with the selection of the synthetic control. Including them might even make the synthetic control more accurate, since these countries are likely similar to France. They share the same political environment with France, which allowed a soda tax to be established. These countries were therefore considered for the synthetic control. The treatment effects for the year 2016 and later might however be 'contaminated', when these countries are included in a synthetic control. In this case the counterfactual consumption will be overestimated, which means that the treatment effects will be underestimated. There is a trade-off between a more accurate counterfactual in the 2012-2015 period and a more accurate counterfactual in the 2016-2019 period. In this case, the initial reaction to the soda tax is more valuable than the reaction in the 2016-2019 period. As shown in table A1, the soda expenditures specification has Norway and Belgium (20%) in the synthetic control, juice consumption has Portugal (27.5%) in the synthetic control and alcohol expenditures has Ireland, UK and Belgium (18.1%) in the synthetic control. The carbonates consumption specification has no countries with a soda tax in the synthetic control.

Another example of an idiosyncratic shock is the ban on unlimited soda refilling in restaurants by France in 2017. The law made it illegal to sell unlimited soft drinks at a fixed price or offer them unlimited for free. All places, from fast-food joints to school canteens were affected (BBC, 2017). It is likely that this law reduced the consumption of soda from 2017 onwards. This effect is also captured by the variables used in this paper, but was not filtered out. It is thus likely that the found treatment effects after 2017 are overestimated because of this ban. There are probably other idiosyncratic shocks that influenced the results, but it is impossible to find and quantify them all or even some. Given the presence of spill-over effects and idiosyncratic shocks it is very unlikely that the synthetic control of all four specifications represent the counterfactual outcomes accurately.

The results of the placebo tests can offer even more certainty. They form, in this case the main obstacle towards attributing any effect to the introduction of the French soda tax. The in-space placebo tests suggest that the found treatment effects are very small and/or at least in part driven by chance. The in-time placebo tests show that there are also treatment effects at an earlier point in time for all four specifications, when there was no introduction of a soda tax at all. Both tests suggest that the found treatment effects cannot be attributed to the French soda tax and can therefore not be considered as causal effects of the introduction of the French soda tax on consumption of soda and alcohol.

*Data*

The soda expenditures and juice consumption variables in the data do not allow for a precise estimate of the isolated effect on taxed goods, since these variables also include untaxed goods. This contaminates the results with potential substitution effects. More precise variables than the ones used, were simply not available. For the carbonates consumption specification this problem does not play a role. There are by definition only taxed beverages in this category. The alcohol expenditures specification also has no problem, since its goal is to investigate potential substitution effects towards all alcoholic drinks.

The carbonates consumption and juice consumption variables were unfortunately only available from 2006 onwards. The result is a relatively short pre-intervention period of five years. First of all, this handicaps the computation of the optimal synthetic control, since the algorithm only has access to 5 years of data to minimize the RMSPE. A longer pre-intervention period would result in a more accurate synthetic control. Second of all, it also hinders the evaluation of the pre-intervention fit of the computed synthetic consumption trends. A synthetic consumption trend that resembles the real consumption trend in the pre-intervention period for, say 10 to 15 years, is considered as more reliable and convincing than a synthetic consumption trend that only resembles the real consumption trend for 5 years. This problem does not arise for the soda and alcohol expenditures specifications. They have a sufficient pre-intervention period of 17 years

In the synthetic control design not all covariates of soda consumption were used. Some good predictors according to the literature were simply not available due to data restrictions. These restrictions mainly consist of measurement inconsistencies over time and between countries, complete lack of data and other measurement issues. Balance in predictors like prices of soda before the tax introduction, household income, amount of soda advertisements and soda availability could be really valuable in assessing whether the real and synthetic France are similar in the pre-intervention period. Which in turn signals that the two are also similar after the intervention (Brownell et al., 2009; World Bank, 2020). It should however be considered when discussing possible predictors to include, that there is also a problem called overfitting.

Overfitting occurs when there are so many predictors that the algorithm is unable to compose a synthetic control at all. There is no synthetic control that can optimally minimize the RMSPE. So there is a limit on how much predictors can be used in the method (Abadie, 2020).

## Conclusion

This paper tried to answer the question, What is the causal impact of the French soda tax on soda and alcohol consumption in France? In conclusion, the effect on soda expenditures of the introduction of a soda tax in France is ambiguous. The absence of an effect could possibly be explained by the combination of a negative effect on carbonates consumption, a positive effect on juice consumption and a substitution effect towards bottled water. The effect on alcohol expenditures was also ambiguous. There are likely spill-over effects and idiosyncratic shocks that cause the synthetic France to be different from the real France, besides the introduction of a soda tax. The results of the placebo tests suggest that the treatment effects cannot be attributed to the introduction of the soda tax in France. Taken together, the found treatment effects do not reflect the causal effect of the introduction of the soda tax in France on soda and alcohol consumption.

With their theoretical research on this topic, Allcott, Lockwood & Taubinsky (2019b) have already established a formula for the optimal soda tax. As discussed in the literature section, the optimal tax depends on the present externalities and internalities, elasticities and redistributional motives of the relevant market. By estimating the required parameters, this framework could in principle be used to provide ex-ante evaluations of what the optimal soda tax should be for every country in the world. Just as the authors did for the United States. Consequently, when a theoretically optimal tax would be implemented by a country, this could pave the way for ex-post evaluations of the optimal soda tax. Researchers can then empirically check the theoretical literature. However unfortunately, there does not seem to be any progress in this regard yet. There are no public records available about implemented optimal soda taxes.

As there are no optimal taxes implemented at this point in time, researchers are constrained to assessing sub-optimal soda taxes. But, as proven by the empirical research of for example Berardi et al. (2016) and Capacci et al. (2019) that was discussed in the literature section, current research is very limited in its scope. Only the effects of a soda tax on consumption and prices are currently estimated. Besides, these studies had difficulties with establishing a causal effect. Unfortunately, this paper also did not succeed in providing an effect that is not contaminated with confounding factors. Causal effects of a soda tax on other economic outcomes like for example distributional outcomes are not investigated yet. This is left to possible future research. Distributional effects could for example be investigated by using consumer level (micro) data, instead of country level (macro) data.

Some of the problems in this paper relating to the synthetic control method itself could be solved by accessing better data sources, if they exist. Monthly consumption data could for example result in a longer pre-intervention period and thus a more reliable counterfactual. Variables that exclusively include all taxed goods would also help establish more accurate treatment effect. Future research should focus on solving these data problems, however problems relating to spill-over effects, idiosyncratic shocks and statistical significance are very hard to solve when employing the synthetic control method.

## Appendix

Table A1 Synthetic control country weights

| Country | Soda expenditures | Carbonates consumption | Juice consumption | Alcohol expenditures |
|---|---|---|---|---|
| Australia | 0.019 | 0 | 0 | 0 |
| Austria | 0 | 0 | 0 | 0 |
| Belgium | 0.130 | 0 | 0 | 0.053 |
| Canada | 0 | 0 | 0.053 | 0 |
| Croatia | 0.199 | 0 | 0 | 0 |
| Czech Republic | 0.259 | 0 | 0.029 | 0 |
| Denmark | - | - | - | - |
| Estonia | 0 | 0 | 0 | 0 |
| Finland | - | - | - | - |
| France | - | - | - | - |
| Germany | 0 | 0.271 | 0.067 | 0.295 |
| Greece | 0 | 0 | 0 | 0 |
| Hungary | - | - | - | - |
| Ireland | 0 | 0 | 0 | 0.082 |
| Italy | 0 | 0.076 | 0 | 0.251 |
| Latvia | - | - | - | - |
| Lithuania | 0 | 0.633 | 0 | 0 |
| Netherlands | 0 | 0 | 0.406 | 0 |
| New Zealand | 0.063 | 0 | 0.168 | 0 |
| Norway | 0.070 | 0 | 0 | 0 |
| Poland | 0 | 0 | 0 | 0.086 |
| Portugal | 0 | 0 | 0.275 | 0.049 |
| Romania | 0 | 0 | 0 | 0 |
| Serbia | 0 | 0 | 0 | 0 |
| Slovakia | 0 | 0 | 0 | 0 |
| Slovenia | 0 | 0 | 0 | 0 |
| Spain | 0 | 0 | 0 | 0 |
| Sweden | 0 | 0.019 | 0.002 | 0 |

| | | | | |
|---|---|---|---|---|
| Switzerland | 0.259 | 0 | 0 | 0.138 |
| UK | 0 | 0 | 0 | 0.046 |
| USA | 0 | 0 | 0 | 0 |

Notes: In this table all 31 countries in the sample are reported with their respective synthetic control weights W for the different specifications. Countries that are not in the donor pool are denoted with a -. The weights are calculated by minimising the RMSPE as explained in the methodology section.

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