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When Industrial Policies Conflict With Population Health: Potential Impact of Removing Food Subsidies on Obesity Rates

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ABSTRACT

Objectives: To model the potential impact on obesity of removing butter, cheese, and sugar subsidies in the Canary Islands.

Methods: A simulation model was applied based on a local data set of subsidies and retail prices (2007-2016), data on own-price elasticity estimates, and representative nutritional and health surveys. We estimated marginal obesity prevalence and population attributable fraction to assess the potential impact of the butter, cheese, and sugar subsidies intervention.

Results: The intervention was predicted to avoid 10 363 obese adults over the study period, because of the reduction of the obesity prevalence by -0.7 percentage points. Overall, the predicted effect was largest in elderly and male groups, although females with a low socioeconomic status experienced the greatest decrease in the prevalence. The population attributable fraction predicted that 4.0% of population with obesity were attributable to the existence of these subsidies.

Conclusions: This analysis provides policy makers with the predicted impact on obesity of the butter, cheese, and sugar subsidies disposal, enabling them to incorporate this health impact into decision making across policy areas in the economic and health field. This study aims to model the potential impact on obesity of removing industrial subsidies for butter, cheese and sugar in the Canary Islands.

Keywords: food subsidies, obesity, sugar/economics, cheese/economics, butter/economics, industrial subsidies, health policy.

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Introduction

The prevalence of obesity has nearly tripled since 1975, with over 650 million obese adults in 2016, which represented 13.0% of the adult population worldwide and where Europe (25.3%) and, specifically, Spain are no exception (27.1%).[1] The obesity epidemic is a global public health issue because of its major contribution to the burden of disease, which accounted for 4 million deaths and 4.9% of global disability-adjusted life-years among adults in 2015.[2] As described in the literature, changes in the food system and in the food environment seem to be the main determinants of weight gain and obesity,[3] so policy actions in these 2 domains need to be implemented to tackle obesity.[4] In the food environment domain, health-related food taxes and subsidies are getting attention as potential population interventions that can encourage healthier food consumption patterns.[5–9] A rationale for sin taxes is to reduce financial externalities when the burden of disease provoked by unhealthy consumption is afforded by others. Behavioral economics points out that there might be also internalities, because individuals do not consume the optimal amount due to lack of self-control and time inconsistency.[10] Policy makers define sin taxes with a long-run criterion for welfare analysis, to help people implement their long-run preferences by reducing consumption of unhealthy food. Although from an economic point of view food subsidies generate an inefficiency in the markets, the focus of this article is another trade-off related to health: the subsidized foods might generate negative externalities and internalities in terms of health. Whereas taxes are generally applied to unhealthy food, as a way of reassessing consumption of the targeted food, food subsidies are meant to overcome barriers to meet healthy preferences.[11] However, existing agricultural subsidies, which aim to ensure a supply of food to the population, have driven overproduction and oversupply of certain products that may have facilitated the increase in energy intake and may have become a hazard to public health.[3,12,13] From the economic analysis perspective, policies targeting economic objectives that have potential effects on population health should be evaluated by comparing both the total social benefits and costs derived from implementing the policy.

Since July 1, 1992, as part of the European Communities Council Regulation 1601/92,[14] the Canary Islands region began receiving subsidies on selected food items—cereals, hops, sugar, vegetable oils, meat, and dairy products, among others—because of its remote and insular geographical situation, based on a yearly forecast supply balance reflected in the regulation. Nevertheless, these specific supply arrangements do not take account of the potential impact of food subsidies on population health, particularly in a region with one of the highest obesity rates in Spain.[15,16] For this purpose, we decided to focus on sugar and butter subsidies due to their association with long-term weight gain.[17] Then we included cheese subsidies as a focus of interest, based not only on its possible association with overweight[18,19] but also on its role as a barrier to healthy food local markets—the competitive disadvantage resulting from the higher cost of local and traditional food products fosters the consumption of imported ones.[20,21] Therefore, the aim of the present study was to model the potential impact on obesity of removing butter, cheese, and sugar (BCS) subsidies in the Canary Islands.

Methods

Model Overview

To assess the effect of removing subsidies to BCS on the prevalence of obesity, we constructed a model that begins by calculating the percent change in food prices attributable to the subsidies and using price elasticity estimates to quantify the change in consumption in a counterfactual—without subsidy—scenario. From this, we obtained the energy intake change and used it to model the expected change in body weight and obesity prevalence. Similar models have been previously used to estimate the impact of taxes on sugar-sweetened beverages and high-sugar snacks.[22–25] The analytical framework of the present study is shown in Figure 1.

Subsidies, Prices, and Price Elasticities

The Canary Islands' specific supply arrangements data—subsidies per product and year—were obtained from the local government's Department for Economic Affairs, Industry, and Trade from 2007 to 2016.[26] Data on prices of BCS from the same period came from the consumer food prices data set, a weekly average prices information of the Ministry of Commerce, Industry, and Tourism of Spain.[27] As estimates for elasticity are generally local and not necessarily linear, price elasticity of demand (PED) values were obtained from a recent published study[28] that estimates own-price elasticities for 10 aggregated food groups in Spain, including cheese, sugar, and oils and fats, by income—proxy of socioeconomic status (SES)—and municipality size, applying an Almost Ideal Demand System method. Although we were unable to identify any country-specific values estimated for cross-price effects, PED and cross-price elasticities concerning BCS for high-income countries reported in recent systematic reviews with meta-regression were used as a sensitivity analysis.[29,30]

As a consequence of removing subsidies to BCS, manufacturers and retailers may pass the extra costs of products onto consumers or absorb some of them by reducing their benefits.[23] Based on the findings of a previous local study,[31] we assumed a 100% pass-on rate to consumers so that a hypothetical elimination of a 10% BCS subsidy would generate a 10% BCS price increase. The BCS price rise combined with the PED values were used to estimate changes in BCS purchases for each year.

Consumption Data and Changes in Total Energy Consumed

BCS and energy consumption data were based on the Canary Islands Nutrition Survey, a local population-based survey conducted in 1997-1998, which consists of a stratified randomly selected sample of 1747 individuals.[32] This survey collected demographic, socioeconomic, nutritional, anthropometric, and health-related information of participants. Two 24-hour recalls were used as the dietary tool instrument, and food composition tables were used to estimate energy intake. Excluding subjects below the age of 18 and without complete anthropometric and nutritional data, a subsample of 1348 participants was finally obtained. To consider total sugar intake, the added sugar contents of foods were estimated from the proportion of free sugars reported in a Spanish study.[33] The estimated change in BCS purchase due to removing subsidies was assumed to have a linear relation with consumption, so that the counterfactual BCS consumption would change in the same quantity as purchases. The change in quantity of BCS consumed for each year were summed to obtain the change in total energy consumed per capita between 2007 and 2016.

Weight Loss and Body Mass Index

To estimate change in weight we used energy balance equations[34] based on change in total energy consumed, which has been previously used to estimate the potential impact of a sugar-sweetened beverages tax on obesity.[24,25] From the potential weight loss, we estimated the change in body mass index (BMI) for each individual in the Canary Islands Nutrition Survey. As the population distribution of BMI has changed much since 1998, a population projection was done to update the effects to the current distribution of BMI in the Canarian population.

Population Projection and Obesity Prevalence

The Canary Islands Health Survey 2015, a population-based survey that consisted of a stratified randomly selected sample of 4155 individuals,[35] was used to estimate variations in BMI and prevalence of obesity in the 2015 population from the derived changes in BMI in the 1998 population. For that purpose, we matched individuals from 1998 and 2015 by age, sex, SES, and deciles of their baseline BMI distributions. Afterwards, we calculated the mean of changes in the distribution of BMI attributable to the intervention for each age, sex, SES, and decile of BMI in the 1998 population and then applied these changes to the BMI of their peers in 2015 (see Appendix C in Supplemental Materials found at https://doi.org/10.1016/j.jval.2020.12.005). From the baseline BMI in 2015 and its counterfactual, we estimated marginal obesity prevalence and the population potential attributable fraction.[36,37] Frequency and sampling weights were considered in population-level estimates; the statistical software used to perform all statistical analyses was Stata/MP version 14.

Results

BCS Subsidies and Baseline Consumption

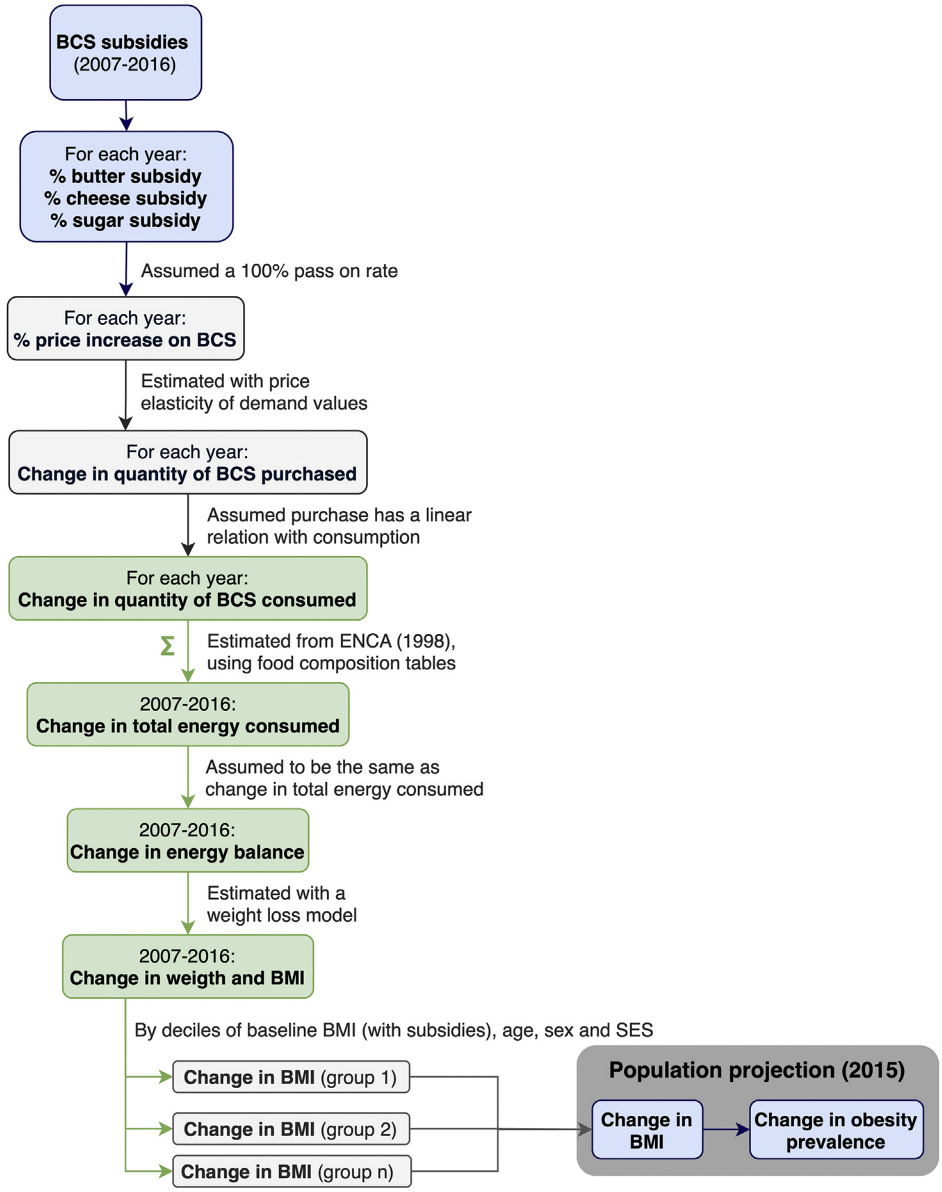
Butter and each type of cheese subsidies have declined from 18.7%, 7.6%, and 5.5% in 2007 to 2.1%, 4.3%, and 1.0% in 2016, respectively. Despite the decline trend, sugar subsidies have remained above 20.0% in the study period (Table 1).

The Canary Islands Nutrition Survey data show an overall highly elevated cheese consumption (60.3 g/day/capita), an average butter consumption of 2.0 g/day/capita, and a 17.6 g/day/capita sugar consumption at baseline. Consumption showed a decline trend as age increased, except for cheese, which registered peak of consumption in the middle-aged group (Tables 2-3). The daily consumption of BCS at baseline by SES can be found in Appendix A in Supplemental Materials found at https://doi.org/10.1016/j.jval.2020.12.005.

Change in Daily Energy Consumption and BMI

Table 4 presents the estimated changes in energy consumption when removing BCS subsidies, by age group and sex. The average

Figure 1. Analytical framework of the impact of removing BCS subsidies on obesity prevalence.



BCS indicates butter, cheese, and sugar; BMI, body mass index; ENCA, Canary Islands Nutrition Survey; SES, socioeconomic status.

reduction in daily energy consumption is -9.3 kcal/capita (95% CI -10.5 to -8.2) when removing butter subsidies, -41.4 kcal/capita (95% CI -43.8 to -39.0) when eliminating cheese subsidies, and -74.7 kcal/capita (95% CI -78.2 to -71.2) when sugar subsidies are the ones removed. The combined effect of removing BCS subsidies results in an overall reduction of -125.4 kcal/capita (95% CI -130.0 to -120.9) in daily energy intake.

At 2015 baseline, the mean BMI was mostly higher in males (26.7 kg/m^2; SD 4.3) than in females (25.7 kg/m^2; SD: 5.0), with the exception of the 65-75 age group, and in low SES (26.6 kg/m^2; SD: 5.2). Supposing BCS subsidies intervention, the overall BMI is estimated to decrease on average by -0.097 (95% CI -0.098 to -0.096), showing the largest reductions in females. Low SES adults were predicted to experience bigger declines in BMI than all others, mainly for sugar subsidies in both sexes where the biggest differences by SES were found (see Appendix A in Supplemental Materials found at https://doi.org/10.1016/j.jval.2020.12.005).

Impact on Obesity Prevalence

Projected changes in the prevalence of obesity by age group, sex, and SES are shown in Table 5 and in Appendix A. The BCS subsidies intervention is predicted to reduce by -0.68 percentage points (95% CI -0.76 to -0.59) the obesity prevalence, which means that 10 363 (95% CI 9057-11 669) cases of obesity would have been avoided over the study period. It was also predicted that the 3.92% (95% CI 3.42-4.43) of population with an obesity status was attributable to the existence of BCS subsidies. A slight reduction in the obesity prevalence is also predicted if only sugar subsidies are removed (-0.24 percentage points; 95% CI -0.33 to -0.16), entailing 2448 cases of obesity avoided in the female population and 1287 cases in males. Neither butter subsidies nor BC subsidies are predicted to change significantly the prevalence rate in both sex adults and in females, respectively. Overall, the predicted effect of removing BCS subsidies in reducing the prevalence of obesity was

Table 1. Prices (€/kg), subsidies, and price elasticities of demand of BCS (2007-2016).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Butter										
Price mean	1.54	1.79	1.93	1.87	1.91	1.97	1.95	1.97	2.00	1.99
Subsidy %	18.71	13.47	7.49	7.73	7.56	7.34	5.19	2.15	2.13	2.14
PED low income	municipality 1: -1.757; municipality 2: -1.775; municipality 3: -1.612									
PED high income	municipality 1: -1.102; municipality 2: -1.093; municipality 3: -1.059									
Cheese A										
Price mean	5.64	5.91	6.22	6.24	7.15	7.10	7.07	7.02	6.91	6.95
Subsidy %	7.64	6.10	5.55	5.53	4.53	4.55	3.65	4.62	4.35	4.33
PED low income	municipality 1: -0.721; municipality 2: -0.722; municipality 3: -0.722									
PED high income	municipality 1: -0.680; municipality 2: -0.680; municipality 3: -0.675									
Cheese B										
Price mean	9.07	9.50	9.85	9.98	10.05	10.26	10.24	10.22	10.30	10.10
Subsidy %	5.51	4.40	4.06	4.01	3.73	3.66	2.93	0.98	0.97	0.99
PED low income	municipality 1: -0.721; municipality 2: -0.722; municipality 3: -0.722									
PED high income	municipality 1: -0.680; municipality 2: -0.680; municipality 3: -0.675									
Sugar										
Price mean	0.51	0.53	0.60	0.61	0.85	0.89	0.96	0.86	0.77	0.76
Subsidy %	38.98	37.58	33.27	32.68	23.40	22.44	20.93	23.23	26.05	26.39
PED low income	municipality 1: -0.903; municipality 2: -0.903; municipality 3: -0.895									
PED high income	municipality 1: -0.685; municipality 2: -0.676; municipality 3: -0.657									

Cheese A: yellow and cream cheeses; Cheese B: Idiazabal, Manchego, and Manouri cheeses.
Municipality 1: more than 100 000 inhabitants; Municipality 2: 10 000-100 000 inhabitants; Municipality 3: less than 10 000 inhabitants.
BCS indicates butter, cheese, and sugar; PED, price elasticity of demand.

largest in the elderly and male groups, although low-SES females experienced the greatest decrease (-1.54 percentage points; 95% CI -1.78 to -1.31).

Sensitivity Analysis

Applying different PED to the model, the BCS intervention predicted to reduce by -0.34 percentage points (95% CI -0.43 to -0.26) the obesity prevalence, which means that 5255 (95% CI 3944-6566) cases of obesity would have been avoided at the end of the study period. When applying PED and cross-price elasticities, the potential effect of removing BCS was a reduction of 0.33 percentage points (95% CI -0.42 to -0.25) in the obesity prevalence, entailing 5120 cases of obesity avoided in the study population (see Appendix B in Supplemental Materials found at https://doi.org/10.1016/j.jval.2020.12.005). Although SES-specific elasticities were not available, low-SES female group is also expected to experience the greatest decrease (-1.10 percentage points; 95% CI -1.34 to -0.86).

Discussion

In this article, we assessed the potential impact of removing BCS subsidies on the obesity prevalence in the Canary Islands. The intervention is predicted to reduce the number of obese adults by 10 363 (-0.68 percentage points) and to skewed BMI distribution to the left slightly, with an increase of 0.55 (95% CI 0.44-0.66) percentage points in the proportion classified as normal weight. If only sugar subsidies are removed, 3735 obesity cases would be avoided (-0.24 percentage points) and a reduction of the overall BMI by -0.06 would be achieved. The results from the sensitivity analysis suggest that if cross effects are considered—by using estimates for high-income countries—the BCS intervention would have showed a lower, but still meaningful, impact on the obesity prevalence of the study population. The substitution patterns would be attributable mainly to the increase in the price of sugar, as a reduction of the consumption of sweets would lead to an increase in consumption of cereals, dairy, fruits, and vegetables.[30] From a food quality perspective, rather than just calorie-focused thinking, intake of rapidly absorbable carbohydrates—sugars and refined starches—may induce neurohormonal changes that might result in metabolic dysfunction and corpulence.[38] Thus, while shifting consumption away from added sugars, the removal of sugar subsidies could potentially reinforce the direct effect of the intervention by fostering the consumption of healthier foods, such as fruit and vegetable intake, that are inversely associated with weight gain and risk of obesity.[39,40]

These results are relatively small compared to an observational study that modeled the effect of a 20% tax on high-sugar snacks and sugar-sweetened beverages, which showed reductions on the average BMI by -0.53 (95% CI -1.01 to -0.06) and a decrease of 2.68 percentage points in the obesity prevalence a year after the introduction of the tax.[22] Another study that modeled the health effects of a tax on sugar predicted an average reduction in body weight of 3.2 kg and a decrease of 4.8 percentage points in the obesity prevalence.[41] These differences could be attributable to the modeling methodology—we specifically modeled isolated sugar consumption (table sugar) and the intake of added sugar on local food production, as imported food products with added sugar are not benefiting from the subsidy; they used an average weight loss of 7715 kcal/kg and a daily 12-20 kcal/kg, respectively—and contextual differences in the baseline population characteristics—differences in sensitivity to price changes—. On the other hand, the withdrawal of butter subsidies did not predict significant changes in obesity prevalence, which concurs with the statement that taxes of at least 10%-20% price change are needed to achieve health gains.[5,6] However, despite the fact that the cheese subsidies were below the threshold mentioned, the cheese intervention was associated with a 0.04 reduction of the overall

Table 2. Daily consumption (g/capita) of BCS at baseline by age group and sex.

Age (years)	n	Butter		Cheese		Sugar	
		Male	Female	Male	Female	Male	Female
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
18-24	194	3.05 (7.49)	3.10 (5.86)	53.59 (65.15)	50.33 (59.28)	21.74 (18.41)	18.93 (19.18)
25-34	252	3.15 (5.58)	2.54 (4.71)	54.45 (62.84)	57.11 (60.31)	18.83 (18.50)	18.62 (19.56)
35-44	162	2.55 (5.40)	2.04 (4.53)	60.14 (55.77)	62.04 (66.01)	16.97 (19.19)	21.01 (20.24)
45-54	247	1.87 (4.64)	1.64 (4.10)	62.71 (56.65)	69.37 (71.63)	21.23 (25.51)	15.43 (15.87)
55-64	217	0.92 (2.40)	1.01 (2.78)	56.14 (55.54)	66.14 (87.52)	16.74 (16.15)	13.79 (13.07)
65-75	176	0.56 (1.76)	0.94 (3.47)	59.53 (71.69)	67.93 (74.62)	14.23 (15.65)	12.43 (13.58)
All	1348	2.11 (5.09)	1.89 (4.38)	57.75 (60.95)	62.40 (70.48)	18.39 (19.42)	16.94 (17.54)

BCS indicates butter, cheese, and sugar; SD, standard deviation.

BMI, which would have a small but relevant impact on the BMI distribution, as an average BMI of 26.1 kg/m^2 (SD 4.7) was registered at baseline. However, the effect of kilocalories from sugar are rather different than kilocalories from cheese or other dairy products in relation to weight gain.[19]

Although comparisons with other studies are not meaningful because of differences in the food products that are taxed and differences in the modeling methodology, our results concur that food taxes and subsidies could influence dietary behaviors and induce population health gains.[5–9] Because products known for their positive health effects—such as fruits and olive oil[42,43]—are also being benefited by the subsidies of the specific supply arrangements, if the amount of BCS subsidies is diverted to these healthy products, the health gains of the intervention might be greater than those predicted in the present study. Furthermore, because type 2 diabetes, cancer, and cardiovascular disease are strongly associated with weight gain,[41,44] the intervention might also lead to reductions in the incidence of these diseases in the long term. Considering that the Canary Islands region has one of the highest mortality rates from diabetes, cardiovascular disease, and certain diet-related cancers in the country,[45] this long-term potential effect would be of great relevance, too. Besides the substantial healthcare costs and other direct costs related to obesity, there are short-term and long-term indirect costs related to overweight and obesity—presenteeism and absenteeism—that could also be avoided if a normal weight status is achieved.[46]

On applying the BCS intervention, it is important to consider the potential impact on the food environment and food system. The food industry could respond to the removal of BCS subsidies by reformulating their products and eliminating or decreasing the targeted ingredients, which would lead to even larger health benefits.[47] The impact of removing sugar subsidies on food manufacturers could be challenging, because sugar is used not only to provide sweetness but also as a food preservative.[48] However, if subsidies are redistributed so that the amount of BCS subsidies are applied to healthy products that are already being benefited from a subsidy—olive oil, whole-grain cereals, or fruits—the intervention not only could yield extra health gains, but also might be more readily accepted and even supported by the food industry. Moreover, the competitive disadvantage resulting from the higher price of local food products may be mitigated by the redistribution of these subsidies, so that the availability and accessibility to healthy food in local markets could be improved.[20] If changes in food prices are applied in tandem with behavior-change communication actions, the longer-term impacts of these policy actions might be greater.[4,49] Besides the mentioned food subsidies, the regulation also includes specific measures concerning agricultural production to promote the development and maintenance of local crop and livestock production.[14] However, this agricultural policy has been unable to avoid the cessation of agricultural activities and might be also interacting with the industrial food subsidies policy. If we aim to assess a sustainability

Table 3. Daily consumption (g/capita) of food groups with added sugar at baseline by age group and sex.

Age (years)	Cereals with AD		Confectionery		Dairy with AD		SSB		Fats, oils, and sauces with AD	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
18-24	127.6 (95.4)	102.9 (78.2)	57.6 (49.4)	55.0 (55.1)	523.2 (333.3)	511.5 (288.1)	227.9 (259.7)	149.5 (175.5)	10.5 (14.6)	8.7 (9.6)
25-34	138.5 (90.1)	83.9 (56.0)	59.2 (80.2)	44.9 (50.9)	430.0 (291.2)	432.0 (273.4)	219.6 (216.6)	125.4 (185.7)	8.9 (10.2)	6.5 (10.6)
35-44	132.6 (86.1)	94.0 (65.1)	48.0 (55.9)	34.1 (38.4)	485.6 (313.4)	450.7 (299.0)	110.6 (132.5)	63.1 (104.5)	5.2 (6.9)	4.3 (6.2)
45-54	129.0 (102.4)	80.1 (49.9)	38.0 (54.8)	27.6 (37.6)	433.0 (298.4)	481.9 (241.4)	74.2 (144.2)	48.3 (115.9)	2.8 (3.7)	3.3 (8.7)
55-64	116.6 (85.4)	94.7 (58.6)	23.8 (33.4)	24.5 (26.6)	408.2 (282.3)	509.9 (212.8)	56.8 (109.5)	55.5 (97.5)	2.2 (3.7)	1.7 (2.7)
65-75	95.2 (71.1)	82.2 (65.5)	25.9 (37.2)	23.4 (27.3)	433.4 (227.5)	447.7 (217.4)	46.2 (102.7)	44.0 (103.9)	1.7 (3.4)	1.5 (3.4)
All	124.9 (90.1)	89.3 (62.2)	43.2 (57.2)	34.7 (42.0)	452.1 (295.9)	471.0 (260.3)	126.6 (186.8)	79.5 (139.6)	5.4 (8.9)	4.3 (8.0)

AD indicates added sugar; SSB, sugar-sweetened beverages; SD, standard deviation.

Table 4. Change of daily energy consumption (kcal/capita) when removing BCS subsidies, by age group and sex.

		Sugar subsidy*		Butter and cheese subsidies*		BCS subsidies*	
		Male	Female	Male	Female	Male	Female
Age (years)	n	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
18-24	194	-101.20 (-114.77 to -87.63)	-87.99 (-101.73 to -74.25)	-50.94 (-62.46 to -39.43)	-49.88 (-60.14 to -39.61)	-152.14 (-168.70 to -135.58)	-137.87 (-156.60 to -119.15)
25-34	252	-90.76 (-104.31 to -77.22)	-79.72 (-91.17 to -68.26)	-52.48 (-61.48 to -43.47)	-50.96 (-58.92 to -42.99)	-143.24 (-161.18 to -125.29)	-130.67 (-145.63 to -115.72)
35-44	162	-74.51 (-86.70 to -62.32)	-82.59 (-93.98 to -71.20)	-52.82 (-61.04 to -44.60)	-53.69 (-62.45 to -44.93)	-127.33 (-141.43 to -113.24)	-136.28 (-151.58 to -120.98)
45-54	247	-85.77 (-102.89 to -68.65)	-61.28 (-70.53 to -52.03)	-52.33 (-60.81 to -43.85)	-54.91 (-63.56 to -46.26)	-130.10 (-157.21 to -118.98)	-116.19 (-129.13 to -103.25)
55-64	217	-63.51 (-74.32 to -52.70)	-57.15 (-65.21 to -49.08)	-43.71 (-51.86 to -35.55)	-49.40 (-60.72 to -38.09)	-107.22 (-120.74 to -93.70)	-106.55 (-119.66 to -93.44)
65-75	176	-55.94 (-67.46 to -44.42)	-52.33 (-62.61 to -42.06)	-42.92 (-53.29 to -32.54)	-49.21 (-59.84 to -38.57)	-98.86 (-115.66 to -82.06)	-101.54 (-116.42 to -86.66)
All	1348	-79.50 (-85.08 to -73.92)	-70.68 (-75.16 to -66.20)	-49.62 (-53.36 to -45.87)	-51.64 (-55.49 to -47.80)	-129.11 (-135.98 to -122.25)	-122.33 (-128.46 to -116.19)

BCS indicates butter, cheese, and sugar; CI, confidence interval.
*PED taken from Lasarte et al.

food system governance, where environmental, social, and economic issues are integrated, there is an inherent need to consider the food system as a whole.[20,50]

This study has a number of strengths and limitations. First, regionally representative data were used to estimate food consumption and baseline BMI distribution. These data were from the 1998 population; we made a 2015 population projection with the assumption that the average changes in consumption by age, sex, SES, and BMI due to the intervention remains the same. However, other factors related to food intake that could not have been taken into account in the present study, such as technology or food suppliers, might have also changed over the study period. Second, although external national PED were used, these were income and municipality size specific to reduce the uncertainty about different effects of food consumption across areas. Even though the present study provides estimates of impact by age, sex, and SES, these were not based on age-, sex-, or BMI-specific price-elasticity estimates. Given that consumption showed a decline trend as age increased, if youths were more or less price-elastic, our results might be under- or overestimating the potential impact on population obesity. High consumers may also be more price-inelastic than low consumers, so that the age effects found might disappear. Although the sensitivity analysis showed a lower health impact of the subsidies, these were based on a systematic review and meta-regression using high-income countries' data, which might not be fully applicable to our population. In addition, as

Table 5. Marginal difference in obesity prevalence (percentage points) when removing BCS subsidies in 2015, by age group and sex.

		Sugar subsidy*		Butter and cheese subsidies*		BCS subsidies*	
		Male	Female	Male	Female	Male	Female
Age (years)	n	Percentage points (95% CI)	Percentage points (95% CI)	Percentage points (95% CI)	Percentage points (95% CI)	Percentage points (95% CI)	Percentage points (95% CI)
18-24	301	0.000 (-0.282 to 0.282)	0.000 (-0.339 to 0.339)	0.000 (-0.282 to 0.282)	0.000 (-0.339 to 0.339)	0.000 (-0.282 to 0.282)	0.000 (-0.339 to 0.339)
25-34	553	0.000 (-0.290 to 0.290)	0.000 (-0.272 to 0.272)	0.000 (-0.290 to 0.290)	0.000 (-0.272 to 0.272)	-0.597 (-0.884 to -0.311)	-0.298 (-0.569 to -0.027)
35-44	876	0.000 (-0.285 to 0.285)	-0.349 (-0.561 to -0.137)	0.000 (-0.285 to 0.285)	0.000 (-0.213 to 0.213)	-0.721 (-1.004 to -0.438)	-0.478 (-0.689 to -0.267)
45-54	918	-0.427 (-0.693 to -0.160)	0.000 (-0.217 to 0.217)	-0.427 (-0.693 to -0.160)	0.000 (-0.217 to 0.217)	-1.122 (-1.387 to -0.858)	-0.695 (-0.909 to -0.480)
55-64	822	-0.186 (-0.516 to 0.144)	-0.598 (-0.901 to -0.294)	0.000 (-0.331 to 0.331)	0.000 (-0.305 to 0.305)	-0.770 (-1.100 to -0.441)	-0.828 (-1.130 to -0.525)
65-75	685	-0.387 (-0.752 to -0.022)	-0.698 (-1.029 to -0.368)	-0.387 (-0.752 to -0.022)	0.000 (-0.332 to 0.332)	-1.066 (-1.429 to -0.703)	-0.808 (-1.138 to -0.478)
All	4155	-0.189 (-0.320 to -0.057)	-0.288 (-0.400 to -0.175)	-0.151 (-0.282 to -0.019)	0.000 (-0.112 to 0.112)	-0.805 (-0.935 to -0.674)	-0.573 (-0.685 to -0.461)

BCS indicates butter, cheese, and sugar; CI, confidence interval.
*PED taken from Lasarte et al.

low-SES families are more sensitive to price change,[51–53] the national PED were SES-specific elasticities, unlike the international ones. Given the lack of information on cross-price elasticity estimates for Spain, we decided to consider cross-price elasticities for high-income countries just as a sensitivity analysis. However, consumer response to price increase by switching from one food product to another within the same food group was not captured, as only substitution effects between food groups were modeled. Although the known linkage between butter, margarine, and olive oil,[54,55] the substitution effects within this food group are not likely to have a great impact on the potential health gain of the intervention, as butter subsidies were not predicted to change significantly the obesity prevalence. Third, we used energy balance equations[34] based on change in total energy consumed, which might not fully reflect mechanisms of weight loss.[56] However, these energy balance equations have been previously used in the literature, among others, to estimate the potential impact of a sugar-sweetened beverages tax on obesity.[24,25]

Once the proposed redistribution of the specific supply arrangements takes place, it would be possible to evaluate the effective health impacts of the intervention. Meanwhile, this is the first study that models the effect on health of removing BCS subsidies of the Canary Islands' specific supply arrangements. The results of the present study could foster the trade-off between economic objectives and population health. To this purpose, a health in all policies approach is needed so that health impact is incorporated into decision making across sectors and policy areas.

Conclusions

The specific supply arrangements from the Canary Islands region included BCS subsidies between 1.0% and the 39.0% of the retail price in the study period (2007-2016). Despite the decline trend in these subsidies, sugar subsidies have remained more than 20.0% during the whole period. Within the limitations and assumptions made in this study, our model predicted an average reduction of -74.7 and -125.4 kcal/capita in daily energy intake attributable to the withdrawal of the sugar and BCS subsidies, respectively. The potential health impact of the BCS intervention was predicted to avoid 10 363 cases of obesity over the study period, as a consequence of the reduction of the obesity prevalence by -0.7 percentage points. Furthermore, it was also predicted that the 4.0% of the population with obesity status was attributable to the existence of BCS subsidies. Elderly and lower SES groups would be the main beneficiaries of the policy, although the intervention might be beneficial to the food environment and system as well.

This analysis provides policy makers with the predicted impact on obesity of the BCS subsidies disposal, making them able to incorporate this health impact into decision making across policy areas in the economic and health field. Additional studies are needed to analyze healthy products that are already being benefited from a subsidy—olive oil, whole-grain cereals, or fruits—and their potential impact on weight gain.

Supplemental Material

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