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Food as a Public Health issue

Diets and their intersection with the health field concept in the Canary Islands

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"Why treat people and send them back to the conditions that made them sick?"
Michael Marmot

"Much can be done by individuals themselves to improve their own health prospects, but whether or not they will actually take such action depends substantially on economic and social structures for which governments are responsible."
Geoffrey Rose

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RESUMEN

Introducción:

Las enfermedades no transmisibles (ENT) constituyen un importante problema de salud en la Comunidad Autónoma de Canarias, principalmente por sus elevadas tasas de mortalidad y morbilidad por obesidad y sobrepeso, diabetes y enfermedades cardiovasculares. Por ello, el estudio de la alimentación y la dieta, así como de sus principales determinantes, cobra especial interés para prevenir y controlar el desarrollo de las ENT. Esta tesis doctoral pretende explorar la asociación entre la dieta y sus determinantes en el sistema alimentario de Canarias, con un enfoque holístico e integrador. Sus objetivos específicos son: (1) analizar si la presión turística afecta a la adherencia a la dieta mediterránea de los habitantes de las Islas Canarias; (2) modelizar el impacto potencial que tendría la eliminación de los subsidios a la mantequilla, el queso y el azúcar (MQA) en la prevalencia de obesidad de Canarias; (3) evaluar el efecto del nivel socioeconómico (NSE), a nivel individual y del área en el que se vive, sobre dos determinantes de la salud –dieta y actividad física en el tiempo libre– en los niños y adolescentes canarios.

Métodos:

Distintos métodos estadístico-econométricos y epidemiológicos han sido empleados para poder responder a cada una de las tres preguntas de investigación de los capítulos correspondientes.

En el capítulo 1, se analiza la influencia del turismo en la adherencia a la dieta mediterránea de la población local, mediante el uso de datos individuales transversales obtenidos de la encuesta poblacional de salud y estilos de vida de Canarias, realizada en 2009 y 2015, y de datos ecológicos de sus zonas de residencia. Se llevó a cabo un análisis de regresión lineal multinivel mediante el método de máxima verosimilitud restringida

para examinar la relación entre la presión turística y la puntuación obtenida en el indicador de adherencia a la mediterránea. Se seleccionaron las zonas turísticas de las Islas Canarias y se definió una puntuación para el indicador de adherencia a la dieta mediterránea (score-DM) que iba de 0 a 11 puntos, basada en la frecuencia de consumo de alimentos declarada por cada residente canario que vivía en esas zonas. Como aproximación a la presión turística existente en cada zona, se emplearon las pernoctaciones turísticas estratificadas por nacionalidad.

El capítulo 2 analiza datos detallados del régimen específico de abastecimiento de Canarias para el periodo de 2007-2016 y los combina con información de la encuesta de base poblacional de nutrición en Canarias para evaluar el efecto potencial que la eliminación de las subvenciones a la MQA tendría sobre la prevalencia de la obesidad. El modelo empleado comienza calculando el cambio porcentual en los precios de los alimentos atribuible a los subsidios y cuantifica, en un segundo tiempo, el cambio que se produciría en el consumo en un escenario contrafactual, utilizando para ello estimaciones de la elasticidad de los precios. A continuación, se calcula el cambio que se produciría en la ingesta energética por la supresión de los subsidios y dicho cálculo se utiliza para modelizar el cambio esperado en el peso corporal y, con ello, en la prevalencia de la obesidad. Los datos sobre los precios de la MQA en el periodo de estudio fueron obtenidos de la base de datos de Precios medios semanales de venta al público de productos de alimentación del Ministerio de Comercio, Industria y Turismo de España, mientras que los valores de la elasticidad precio de la demanda (EPD) se obtuvieron de un estudio publicado recientemente en España. Como análisis de sensibilidad, se emplearon los valores de EPD y de elasticidades cruzadas de la MQA publicados en una reciente revisión sistemática con metarregresión para países de renta altas.

El capítulo 3 estudia el efecto del NSE, a nivel individual y del barrio en el que se vive, sobre dos determinantes de la obesidad –dieta y actividad física en el tiempo libre– en los niños y adolescentes canarios. Con los microdatos registrados en las visitas al pediatra o enfermera del centro de salud como parte del programa del niño sano del Servicio Canario de la Salud en 2018, se emplearon modelos multinivel para estimar el efecto simultáneo de las desigualdades en el NSE –nivel individual y del barrio– sobre un indicador de hábitos saludables, con puntuaciones de 0 a 4 puntos. La adherencia a las recomendaciones dietéticas y de actividad física se evaluaron a partir de dos cuestionarios breves, de respuesta dicotómica, disponibles en la historia clínica electrónica. El nivel de adherencia a la guía de alimentación del Servicio Canario de la Salud se obtuvo a partir de dos indicadores –la ingesta de frutas y verduras y el consumo de bebidas azucaradas y dulces–, mientras que la adherencia a la actividad física se determinó en base al cumplimiento o no de la recomendación de realizar al menos 60 minutos diarios de actividad física.

Resultados:

En el primer estudio, se observó una asociación negativa significativa entre la puntuación del score-DM y la presión de los turistas británicos ($\beta = -0{,}0064$, $p = 0{,}010$), lo que significa que 10 millones de pernoctaciones de turistas británicos se asociaron con una disminución de 0,64 en la puntuación del score-DM de la población local. Con la presión turística de alemanes ocurrió lo contrario, ya que se observó una asociación positiva al borde de la significación estadística ($\beta = 0{,}009$, $p = 0{,}04$). Asimismo, se produjo un cambio estadísticamente significativo en la puntuación del score-DM entre la cohorte del año 2009 y la de 2015 ($\beta = -0{,}021$, $p < 0{,}01$).

En el segundo estudio se predice que la intervención de los subsidios a la MQA habría reducido en 10363 personas el número de adultos obesos (-0,68 puntos porcentuales; IC95%: -0,76 a -0,59) y que habría desplazado ligeramente la distribución del IMC hacia la izquierda, con un aumento de 0,55 (IC95%: 0,44 a 0,66) puntos porcentuales en la proporción de personas con normopeso. En general, la disminución prevista en la prevalencia de obesidad con la eliminación de los subsidios a la MQA fue mayor en los grupos de edad avanzada y de hombres, aunque las mujeres de bajo NSE experimentaron la mayor disminución. Los resultados del análisis de sensibilidad sugieren que, si se tuvieran en cuenta los efectos cruzados, la intervención de la MQA habría mostrado un impacto menor, pero aún significativo, sobre la prevalencia de obesidad de la población a estudio.

El tercer estudio demostró que la adherencia a las recomendaciones dietéticas y de actividad física era significativamente menor en los niños que vivían en familias menos acomodadas ($p < 0,01$) y en zonas con un mayor porcentaje de personas con ingresos anuales por debajo del umbral de los 18000 € ($p = 0,03$). Las niñas, los extranjeros y los grupos etarios mayores mostraron una menor adherencia a las recomendaciones sobre dieta y actividad física ($p < 0,01$). Las diferencias encontradas en la puntuación del indicador de hábitos saludables entre las distintas áreas fueron de poca relevancia, ya que estas variaciones representaban sólo el 1,8% de la varianza individual total en ambos modelos. Además, el pequeño cambio proporcional en la varianza encontrado (3,5%) sugiere que los efectos contextuales generales no estaban sustancialmente mediados por el NSE del vecindario.

Conclusiones:

La importancia que tiene sobre la dieta el entorno en el que se vive se pone de manifiesto, al observarse cómo la presión turística influye en la adherencia a la dieta mediterránea de la población canaria. El NSE de los turistas podría estar siendo determinante en la dirección de este efecto, induciendo cambios en los hábitos alimentarios de la población local. Por otro lado, se predice que la retirada de las subvenciones del régimen específico de abastecimiento al azúcar y a la MQA habría más de 10.000 casos de obesidad en las Islas Canarias durante el periodo de estudio, a consecuencia de una reducción de -0,7 puntos porcentuales en la prevalencia de obesidad entre 2007-2016. Las personas mayores y los grupos de menor NSE serían los principales beneficiarios de esta política, aunque la intervención podría también ser beneficiosa para el sistema alimentario. Por último, se confirma que los hábitos saludables en niños siguen un gradiente socioeconómico, tanto a nivel individual como del barrio, de modo que los niños de familias y zonas más acomodadas muestran mayores niveles de adherencia a las recomendaciones dietéticas y de actividad física. En resumen, esta tesis doctoral explora la asociación entre la dieta y sus determinantes mediante el análisis del sistema alimentario en Canarias, contribuyendo así a la generación de conocimiento en el ámbito de la salud pública, y favoreciendo la implantación de nuevas políticas sanitarias y económicas, ya que arroja luz sobre cuestiones que no habían sido abordadas hasta el momento en Canarias.

ABSTRACT

Introduction:

Non-communicable diseases (NCDs) are a major health problem in the Canary Islands autonomous region, mainly because of the high mortality and morbidity rates due to obesity and overweight, diabetes and cardiovascular disease. For this reason, the study of food and diet, and its main determinants become of especial interest to prevent and control the development of NCDs. This PhD dissertation aims to explore the association between diet and its determinants across the food system in the Canary Islands, with a holistic and integrative approach. The specific aims are: (1) to investigate whether tourist pressure affects Canary Islands inhabitants' adherence to the Mediterranean diet; (2) to model the potential impact on obesity of removing butter, cheese, and sugar (BCS) subsidies in the Canary Islands; (3) To assess the effect of socioeconomic status (SES) at the individual and neighbourhood level on two health determinants –diet and leisure time physical activity– among the Canary Islands children and adolescents.

Methods:

Different statistical-econometric and epidemiological methods are used to answer each of the three research questions of the corresponding chapters.

Chapter 1 analyses the influence of tourism on the adherence to the Mediterranean diet in the local population, combining cross-sectional individual data from the Canarian health and lifestyle population-based survey conducted in 2009 and 2015 with ecological data of the areas of residence. A multilevel linear regression analysis by restricted maximum likelihood estimation was performed to examine the relationship between tourism pressure and the Mediterranean diet score. Touristic areas in the Canary Islands were selected, and a Mediterranean diet score (MD-score) was defined (0 to 11 points),

based on the reported intake frequency for each Canarian resident living in those areas. Tourism pressure in each area was proxied through tourist overnight stays, stratified by nationality.

Chapter 2 analyses detailed data from the specific supply arrangements of the Canary Islands in 2007-2016 and links them with information on a population-based nutrition and health survey of the Canarian population to assess the potential effect of removing BCS subsidies on the prevalence of obesity. The model constructed 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 scenario. From this, the energy intake change was obtained and used to model the expected change in body weight and obesity prevalence. Data on prices of BCS from the study period came from the consumer food prices data set of the Ministry of Commerce, Industry, and Tourism of Spain and price elasticity of demand (PED) values were obtained from a recent published study in Spain. PED and cross-price elasticities concerning BCS for high-income countries reported in a recent systematic review with meta-regression were used as a sensitivity analysis.

Chapter 3 addresses the effect of socioeconomic status (SES) at the individual and neighbourhood level on two obesity determinants –diet and leisure time physical activity– among the Canary Islands children and adolescents. Using population-based microdata from the Canary Health Service well-child visits to their primary care doctor or nurse in 2018 and multilevel models, the simultaneous SES inequalities effect –individual and neighbourhood level– on a healthy habit score (0 to 4 points) was estimated. Adherence to dietary and physical activity recommendations were assessed by two short questionnaires on a two-point yes/no scale from the electronic health records. The level of adherence to the dietary guidelines issued by the Canary Health Service was the result of two indicators –fruit and vegetables intake and SSB and sweets consumption–, and adherence on physical activity was achieved when the recommendation of 60 minutes per day of physical activity was fulfilled.

Results:

In the first study, a significant negative association between the MD-score and British tourists' pressure was observed ($\beta = -0.0064$, $p = 0.010$), which means that 10 million British tourists' overnight stays were associated with a 0.64 decrease in the MD-score in the local population. The opposite was observed with German tourist pressure, which showed a borderline significant positive association ($\beta = 0.009$, $p = 0.04$). Thus, between the 2009 and the 2015 cohort of participants, the MD-score significantly changed ($\beta = -0.021$, $p < 0.01$).

In the second study, the BCS subsidies intervention is predicted to reduce the number of obese adults by 10363 (-0.68 percentage points; 95% CI -0.76 to -0.59) 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. Overall, the predicted effect of removing BCS subsidies in reducing the prevalence of obesity was largest in the elderly and male groups, although low-SES females experienced the greatest decrease. The results from the sensitivity analysis suggest that if cross effects are considered the BCS intervention would have showed a lower, but still meaningful, impact on the obesity prevalence of the study population.

The third study showed that adherence to the dietary and physical activity recommendations seemed to be significantly lower in children living in less affluent families ($p<0.01$) and in areas with a higher percentage of annual incomes below the €18,000 threshold ($p=0.03$). Girls, foreign-born and older children showed a lower adherence to the diet and physical activity recommendations ($p<0.01$). Differences in the healthy habits score areas seemed to be of minor relevance, as these variations represented only 1.8% of the total individual variance in both models. Thus, the small proportional change in variance found (3.5%) suggest that the general contextual effects were not substantially mediated by the neighbourhood SES.

Conclusions:

The importance of the environmental context on diet is recognized, as tourist pressure influences the adherence to the Mediterranean diet pattern in the Canary Islands' population. The SES of tourists might be determinant in the direction of the effect, driving food habits of the inhabitants. On the other hand, the potential withdrawal of the sugar and BCS subsidies from the specific supply arrangements of the Canary Islands was predicted to avoid more than 10000 cases of obesity over the study period, due to the reduction of the obesity prevalence by -0.7 percentage points in 2007-2016. Elderly and lower SES groups would be the main beneficiaries of the policy, although the intervention might be beneficial to the food system as well. Finally, healthy habits in children followed a socioeconomic gradient at the individual and the neighbourhood level, so that children from more affluent families and areas show higher levels of adherence to the dietary and physical activity recommendations. In summary, this PhD dissertation explores the association between diet and its determinants across the food system in the Canary Islands, contributing to public health knowledge, but also to health and economic policies, as it sheds light on issues that had not been considered so far in the Canary Islands.

1. INTRODUCTION

1.1. Food and health

1.1.1. Health effects of diet

Food is a fundamental determinant of the health status of the population, with diet being one of the main modifiable risk factors in the development of non-communicable diseases (NCDs), such as obesity, diabetes, cardiovascular disease, and cancer (Joint WHO/FAO Expert Consultation, 2003; Shetty, 2015). Since 1992, the WHO has highlighted the need to prevent and control the worrying increase in NCDs by promoting healthy diets and other healthy habits. Healthy dietary practices to protect against NCDs include a high intake of fruit, vegetables, legumes, nuts, and whole grains, combined with a low intake of salt, free sugars, sugar-sweetened beverages (SSB), and trans-fat (Joint WHO/FAO Expert Consultation, 2003; World Health Organization, 2012, 2015).

Based on the 2019 Global Burden of Disease Study (Murray et al., 2020), 47.1% of global population were exposed to dietary risks such as low intake of fruits and vegetables or a diet high in SSB and this, in turn, is a key factor in the rapid increase in the prevalence of obesity worldwide (Mozaffarian, 2016; Swinburn et al., 2011). Although WHO has targeted diet as a critical part of health that requires global action, a slight but significant decline trend in the exposure for dietary risks globally is shown in the last decade (Murray et al., 2020). In fact, dietary risks are the second and third leading risk factor for attributable deaths in females and males, respectively, accounting for around 8 million deaths in 2019, and the fifth leading risk factor globally for disability-adjusted life-years

(DALYs), estimated to cause 7.4% of DALYs, 187.7 million (Institute for Health Metrics and Evaluation, 2019). The leading dietary risk factors on mortality include high sodium, sugars and trans fatty acids intakes, and diets low in wholegrains, legumes, fruits, and vegetables, with cardiovascular diseases as the main cause of death. On the other hand, more than half of diet related DALYs were attributable to a high intake of sodium (44.9 million), and diets low in whole grains (42.6 million) and fruits (27.7 million) (Figure 1). Even though certain diet components are more likely to influence weight regulation (Mozaffarian, 2016), the combined burden of diet risk factors and high body mass index (BMI) reached around 350 million DALYs in 2019 (Institute for Health Metrics and Evaluation, 2019).

Unhealthy diets not only affect people's quality of life and expectancy, but also generate an economic burden. For instance, poor diet-related ill health in the United Kingdom cost €8.5 billion to the National Health Service in 2006, being much of that burden due to overweight and obesity (Scarborough et al., 2011). In 2015, the estimated economic cost of unhealthy diets related to diabetes mellitus type-2 and its complications was €11 million in Spain and €44 million and the United Kingdom, considering both direct health care cost and indirect costs –productivity days lost due to absenteeism and presenteeism; working years lost due to work disability, early retirement, and premature death– (Candari et al., 2017).

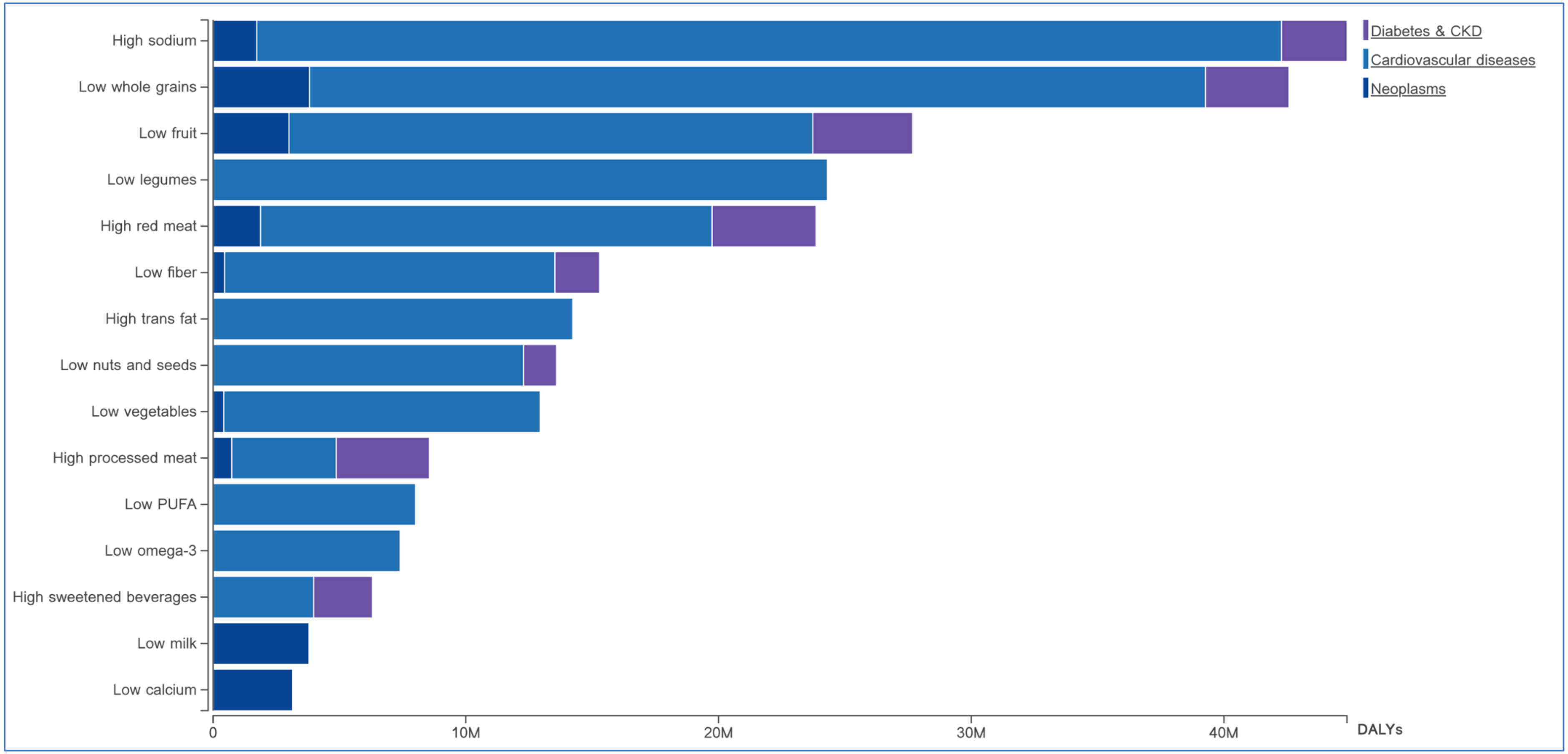

Figure 1. Number of DALYs (in million) attributable to individual dietary risks at the global level in 2019. Source: Institute for Health Metrics and Evaluation, 2019.

1.1.2. Definition and methods to measure diet.

Traditional epidemiology has used the nutritional approach –chemical composition or nutrient content of diet– to study the relationship between diet and health. This approach investigates causal relationships between nutrients and NCDs, providing the most powerful test of a hypothesis which serve as the basis for setting nutritional targets at the population level.

On the other hand, diet can be described in terms of foods or food groups –dietary approach–, allowing to assess the potential effect of food on the development of NCDs. The main advantage of this approach is the transfer of the knowledge generated to the population through the development of dietary recommendations –which foods to eat and their frequency of consumption– (Willett, 2012). However, there are joint and antagonistic chemical effects on the foods and nutrients that people consume and interrelations due to individual behavioural patterns, which often make it difficult to predict with certainty their health effects given the small magnitude of the effects studied (Candari et al., 2017; Hu, 2002; Willett, 2012).

The complementary approach of dietary patterns –dietary habits– is the one that allows for a comprehensive analysis of the complex effect of diet on health, as it considers the balance among all food groups, characterize dietary patterns, and aggregate them empirically (Candari et al., 2017; Willett, 2012). It is also a method for assessing the health effects of adherence to dietary guidelines by individuals, while favouring the development of dietary guidelines and policies (Hu, 2002; Sánchez-Villegas et al., 2003). Regardless of the method used for the definition of dietary patterns –theoretical (dietary indices) or empirical (factor or cluster analysis)–, two main types are identified: 1. the western pattern, characterised by a high consumption of red meat, processed foods, refined grains, fast food and high-fat dairy products; and 2. the prudent or healthy pattern, represented by a diet rich in fruits, vegetables, legumes, fish and poultry (Kontogianni & Panagiotakos, 2014; Magalhães et al., 2012; Sánchez-Villegas et al., 2003). This healthy pattern includes diets such as the Mediterranean diet and DASH (Dietary Approaches to Stop Hypertension), known for their heart-healthy and chemopreventive qualities (Kontogianni & Panagiotakos, 2014; Magalhães et al., 2012; Martínez-González et al., 2015; McEvoy et al., 2014).

As previously stated, there is no single approach to assessing diet and its potential impact on health, as all have both advantages and drawbacks. The choice of one method or another will depend on the hypothesis to be studied and the availability of food and dietary data (Willett, 2012). In addition, efforts have been recently putted in assessing the impact of food systems on human and environmental health, analysing not only the impact of food patterns but also considering how and where these foods are produced, stored, distributed, and consumed (HLPE, 2017).

1.1.3. Epidemiology of diet: metrics and trends

During the second half of the 20th century, there has been a worldwide phenomenon of nutritional transition that has resulted in the progressive abandonment of healthy diets in favour of the adoption of western dietary patterns (Bermudez & Tucker, 2003; Donini et al., 2015; Popkin, 2004), thus jeopardising the multiple health and wellness benefits associated with the prudent pattern (Kontogianni & Panagiotakos, 2014; Magalhães et al., 2012; Martínez-González et al., 2015; McEvoy et al., 2014) and its quality as a sustainable dietary model (Donini et al., 2015; Sáez-Almendros et al., 2013).

Although there are no harmonized metrics for global monitoring of diets, there are some existing indicators to track progress towards food habits (World Health Organization, 2021b). The Global Burden of Disease Study selected 15 dietary risk factors among adults aged 25 years old or older across countries to estimate their effect on NCD morbidity and mortality (Murray et al., 2020). In 2019, 47.1% of worldwide population were exposed to these dietary risks, with a slight but significant decline trend in the last decade (-0.3%). Exposure to diets with high soft drinks consumption –mean daily consumption of SSB– was estimated at 30.4% of the worldwide population, with a non-statistically significant increase of 0.38% in 2010-19. On the other hand, 56.9% and 40.2% were exposed to diets low in fruits and vegetables, respectively, with a significant rate of change in the fruit consumption in the past decade (-0.4%). As part of the Global Burden of Disease Study in 2017, a special analysis on dietary data was carried out. Globally, daily intake of unhealthy foods exceeded the optimal level, especially SSB consumption with the highest intakes observed among young adults, in high-income North America, and Central and Southern Latin America. The highest consumption of vegetables was registered in North Africa, Middle East and in Central Asia, although only the last one reached the optimal level of vegetables intake (360g per day). Regarding fruits consumption, the Caribbean was the region with the highest intake, but far away the 250g per day defined as the optimal intake level (Afshin et al., 2019).

Indicators on the consumption of fruit and vegetables are included as core health indicators in the European Union (EU) too, and the European Health Interview Survey also provides information on SSB consumption. In 2019, 67.1% of EU population aged

15 and over reported a daily eating of fruit and vegetables, a slight increase of 3.1 percentage points compared to 2011. Among the countries with a daily consumption of fruit and vegetables above 75.0% of their population (Belgium, Ireland, Italy, and Spain), Spain and Ireland showed a growth compared to 2011. However, only Ireland and Italy reported a daily consumption of at least five portions in about a quarter of their population in 2019 (12.4% EU, 10.9% Spain). Globally, the proportion of people eating at least five portions of fruit and vegetables per day was greater among people with higher income. In addition, frequent consumption of SSB appear to be in the minority, as 66.1% of the EU population declared to consume SSB less than once a week or never. While Belgium was the country with the highest share of population with a daily intake of SSB in 2019 (20.4% Belgium; 9.1% EU), 10.0% of the Spanish population reported a SSB consumption of four to seven times a week (6.4% daily intake) and 20.1% one to three times a week (Eurostat, 2022). However, SSB consumption seem to be higher in European children, as around 13-15% reported a daily intake of SSB in 2014 (Inchley et al., 2016). In Spain, 5.5% of children under 15 years of age reported a daily intake of soft drinks in 2017 (Ministerio de Sanidad, 2018).

Since the stabilization of the downward trend on world hunger in 2014, all forms of malnutrition –undernutrition (wasting, stunting, underweight and micronutrient deficiencies), overweight and obesity– have increased worldwide. Although low and middle-income countries (LMIC) are still dealing with undernutrition, new forms of malnutrition are emerging. For instance, children under five years in Africa and Asia account for more than seven out of ten children who are overweight globally (FAO et al., 2021), and around 46.5% of countries with available data are suffering from doble burden of malnutrition –undernutrition and overweight/obesity– (International Food Policy Research Institute, 2016).

1.2. Global Food System and Public Health Nutrition

1.2.1. The food system

Diets, composed of food choices –preferences and purchase habits– and eating behaviours –frequency and quantities of food consumed– (Hu, 2002), are complex processes influenced by the interaction of multiple factors from the food system that impact on nutrition and health (HLPE, 2017; Story et al., 2008; Swinburn et al., 2013). Although many food system frameworks have been proposed across different disciplines (Stok et al., 2017), in general, all agree that the food system consists of some interdependent main components or domains and external drivers that jointly influence diets (Figure 2).

Firstly, the individual-level determinants of diet that include (1) biological –age, gender, and genetics–, (2) demographic –income, social status, ethnicity, etc.–, (3) cognition –knowledge, skills, and attitudes– and (4) lifestyle factors. These individual factors interact with the food environments to shape consumers behaviour and thus their diets (Story et al., 2008; Swinburn et al., 2013).

Environmental contexts related to diet include (1) the physical or built environment –availability (type and diversity of food on offer) and physical access to food in the living environment (location and type of retail outlets at schools, work sites and neighbourhoods)–, (2) the economic access to food –affordability (relative cost of food compared with a household's income and expenditure)–, (3) the food messaging –marketing campaigns, labelling of foods, and dietary guidelines– and (4) the food quality –attributes (size, shape, colour, flavour, composition and way of production)– and safety

(HLPE, 2017; Stok et al., 2017; Story et al., 2008; Swinburn et al., 2013). The food environments act as linking factors between the demand system –consumers behaviour– and the supply one –food supply chain–.

The food supply chain is made up of the activities and actors that take food from its conception to its disposal or its waste, including (1) food production systems and input supply, (2) storage and distribution, (3) processing and packaging, (4) retail and markets (Hawkes & Ruel, 2012; HLPE, 2017).

Finally, external drivers of the food system include (1) demographic –population growth, migration, urbanization, gentrification–, (2) sociocultural –social norms and traditions, religious values and practices–, (3) political and economic –income growth and distribution, globalization, trade agreements, land tenure and use, fiscal and agricultural policies–, (4) technological –infrastructure and technology innovations– and (5) environmental factors –natural resources and climate change– (HLPE, 2017; Swinburn et al., 2013).

The conceptual framework shown on Figure 2 underlines the complex links between food systems and their final nutrition and health outcomes, so that actions or policies aimed at just one determinant into a core component (e.g. food labelling) might have an impact not only in the same domain (e.g. food properties) but also in the others (e.g. food processing and packaging). Consequently, interventions to promote healthy eating would necessarily need to consider the interactions across the different domains of the food system to succeed. Yet, these linkages are constantly evolving, so a dynamic approach would be needed to guide future research on nutrition and health (Stok et al., 2017).

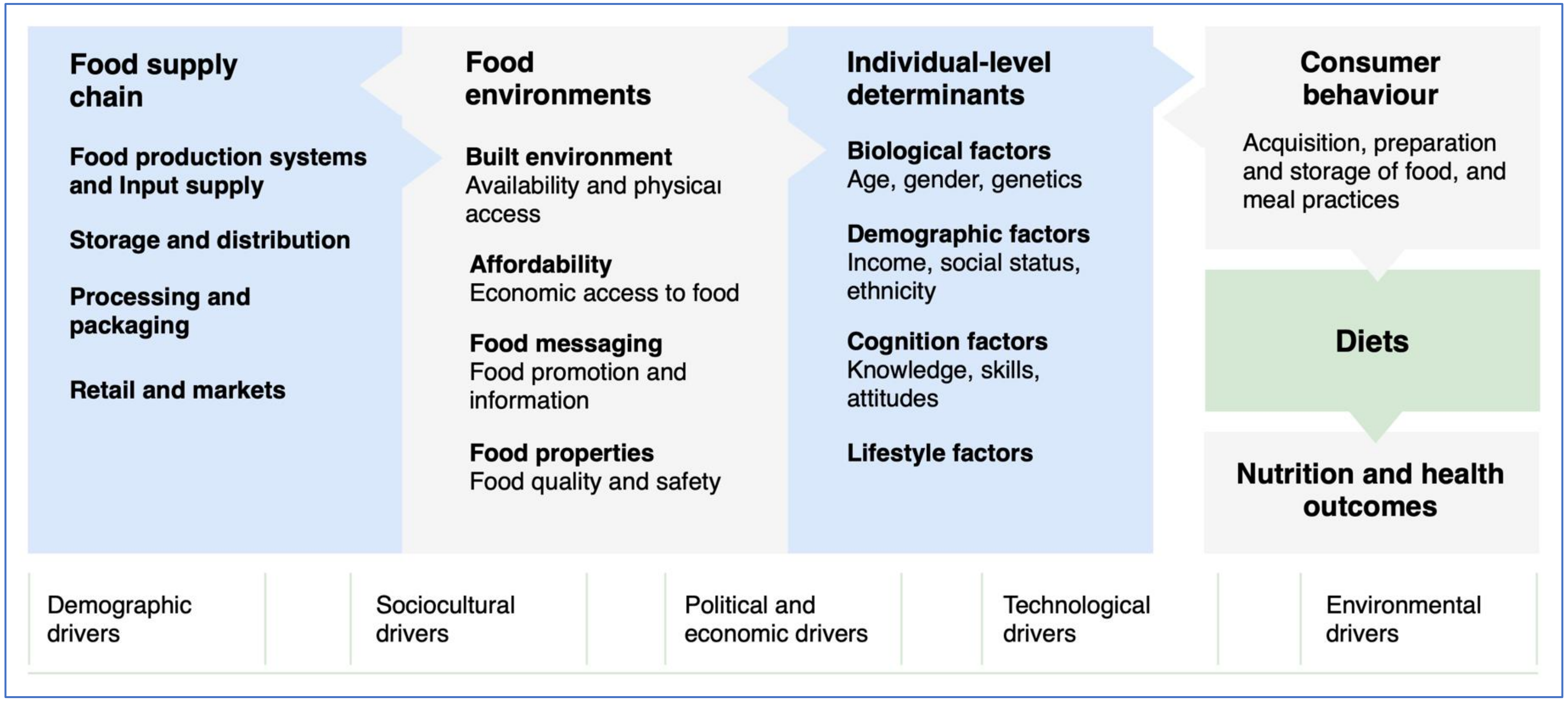

Figure 2. Food system conceptual framework. Source: adapted from Global Nutrition Report, 2022 and HLPE, 2017.

1.2.2. Nutrition equity

Given the crucial role of the food system in nutrition and health outcomes, and its interactions and features between domains and external drivers, it is not surprising that isolated inequalities in the food system can have a major impact on population's health. So tackling inequalities in any component of the food system, we could diminished or even reversed the negative health impact generated (Global Nutrition Report, 2020).

Regarding inequities across the food environments, the built environment can restrict availability and access to healthy diets for some population groups, mainly the most vulnerable ones (Walker et al., 2010). People living in isolated regions (e.g., rural areas or islands) or with an inadequate infrastructure (e.g., scarce means of transport) can have a limited offer and access to some types of foods, especially perishable ones in favour of more processed foods with an extending shelf-life (HLPE, 2017), resulting in an increased exposure to unhealthy diets. Thus, density of retail outlets seems to vary depending on the location or setting, with a greatest access to fast food retailers in more deprived neighbourhoods (Moore & Diez Roux, 2006; Walker et al., 2010; Zenk & Powell, 2008).

To be able to consume healthy foods, economic access must also be granted. However, low-income areas have fewer retail outlets and their relative food expenditures tend to be much higher than affluent ones (HLPE, 2017). Because highly processed foods are cheaper, deprived areas have access to a greater offer of unhealthy foods (Walker et al., 2010).

Inequities can also be found on food quality and safety. For instance, food processing can alter food nutritional values –by removing key nutrients or by adding ingredients that should be limited for health reasons– but improve their palatability, tastiness and convenience (Augustin et al., 2016). On the other hand, lack of cold-chain storage and transport, the use of pesticides or the overuse of antibiotics are some examples of a compromised food safety (HLPE, 2017).

As stated previously, information provided about food and marketing campaigns are potent determinants of diets, mainly in children and youth as eating behaviours are shaped during these life stages. Marketing strategies focus more frequently in the promotion of energy-dense, nutrient-poor products in low SES areas and LMIC (Bragg et al., 2017). In addition, inequalities may occur due to nutrition labelling, as the mandatory nutrition declaration of food products can be more difficult to understand by populations with lower literacy levels. However, the evidence related to consumer comprehension of labels is limited (Campos et al., 2011; Mandle et al., 2015).

There is a growing disconnect between agricultural policies, food consumption trends and contemporary nutritional challenges that fosters malnutrition in all its forms –undernutrition, overweight and obesity–. Agriculture investments seek staple grain oilseeds productivity among other crops, resulting in an over production of maize, rice, wheat, sugar, soybeans and oil palm, which runs counter to the balance in food availability and highlights the need of a more diverse production systems (Khoury et al., 2014; Pingali, 2015). Although there has been a decline in the per capita intake of staple cereals, global average energy consumption has risen due to an increase in food energy from non-staple crops, which are relatively more nutrient-dense (Pingali, 2015).

Inequalities on storage and distribution of food supply chains are more common in remote regions. Because of the high cost of transportation to these areas and the difficulty in maintaining the cold chain during transport, importer distributors prefer delivering non-perishable foods (e.g., processed foods), so population might have little access to fresh food such as fruits, vegetables, and animal-source foods if no shorter-distance supply chains are available (HLPE, 2017).

Processed foods, especially highly processed ones –ultra-processed foods–, comprise a significant share of many diets worldwide (Figure 3). Although a wider variety of processed foods are sold in richer countries, sales are increasing modestly or even declining in most of them but growing rapidly in LMIC. Thus, declines in sales of carbonated soft drinks in affluent areas have been offset by an increase in ready to drink coffee and tea, as well as sports and energy drinks (Baker et al., 2020).

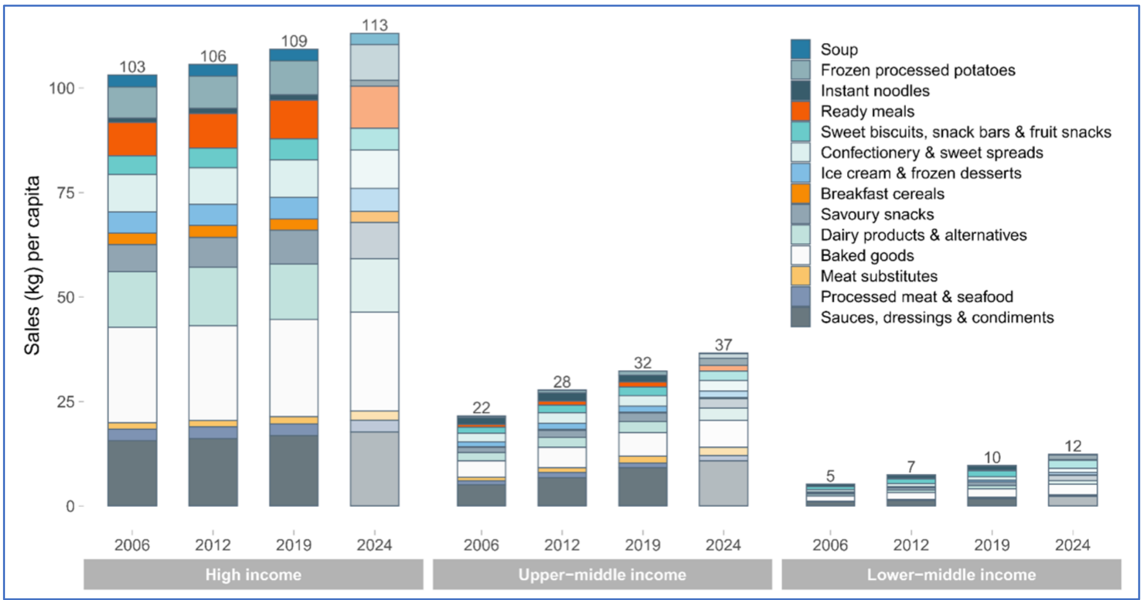

Figure 3. Ultra-processed foods sales (kg) per capita by country income level, 2006-19 with projections to 2024. Source: Baker et al., 2020.

The rapid spread of supermarkets and fast-food chains impacts relationships within food supply chains, so that market power is moving from farmers and producers to traders and retailers from multinational corporations, which put pressure on the former to supply a larger volume of product of higher quality and at a lower price (Reardon & Timmer, 2008). This is of concern, given that the interests of multinationals are not usually aligned with nutrition and health goals despite their responsibility to promote healthy diets under human rights principles.

Currently, the underlying drivers behind inequalities in the food system worldwide are mainly environmental, technological, and political and economic drivers (FAO et al., 2021). Due to climate change, countries are increasingly exposed to climate variability – in temperature and rainfall– and extremes –droughts, floods, storms, extreme heat, etc.–. For this reason, countries highly sensitive to climate variability and extremes or with a highly dependent livelihood on agriculture would be the ones with a major negative impact on their food systems (FAO et al., 2018). Among political and economic drivers, conflicts and humanitarian causes, trade liberalization, the expansion of multinational corporations and the failure of policies and regulations designed to promote healthy diets are the main factors responsible for inequalities in the food system (FAO et al., 2021; Kearney, 2010).

The interconnected causes of inequalities in food systems require an integrated, coordinated and multisectoral response at global, national and local levels, which is ultimately about addressing power imbalances –amplifying the voice of those excluded and claiming for better governance and accountability from those in power– (Global Nutrition Report, 2020; HLPE, 2017).

1.2.3. Public Health Nutrition

Public health nutrition is the science that studies the relationship between diet and health and provides the basis for the design, implementation, and evaluation of nutritional interventions at community and population levels to improve the health status of populations with a multidisciplinary approach (Serra & Aranceta, 2006).

Diets can be modified through political and institutional actions aimed to tackle inequalities in the food system. Below are some examples of policies that can be implemented across the food system domains to improve diets and nutritional and health outcomes on population.

To address inequalities on the food supply chains, food processing policies and programmes have targeted foods and beverages that are high in added saturated fat, salt, or sugar in some countries (Popkin et al., 2021) and adequate storage and transport infrastructures have been developed –taking advantage of technological innovations that aims to preserve perishable foods– (FAO, 2015). Solutions to increase diversification of production systems include improvements in production practices by using intercropping and irrigation systems, guaranteeing a market for local producers (e.g., the farm-to-school programmes) or the promotion of urban agriculture, among others (Baker, 2004; Kerr et al., 2007; Prescott et al., 2020). In addition, actions aimed at increasing market penetration of local producers could also influence power forces and thus inequalities in retail and markets.

On the other hand, there are many examples of policies and programmes that could be implemented in the food environment. In modern food systems, improvements in the built environment means tackling low income areas where people face barriers to accessing nutritious food –"food deserts"– and others where most vulnerable people are overexposed to unhealthy food options –"food swamps"– (Swinburn et al., 2019; Walker et al., 2010). Mobile markets, encouraging outlets to offer healthier options, and improving transportation systems –including active means of transport– are some examples of actions to deal with availability and accessibilities barriers (Hsiao et al., 2019; Mayne et al., 2015). To face affordability problems, discriminatory trade policies can be set up to restrict unhealthy foods and encourage healthier diets through the use of taxes and subsidies (Cabrera Escobar et al., 2013; Eyles et al., 2012; Mayne et al., 2015). Finally, strengthening regulations for advertising and marketing, as well as adopting easy-to-interpret food labels we can foster healthier diets by influencing consumers to purchase healthier products and providing an incentive to industry to reformulate their products (Hersey et al., 2013; Kraak et al., 2016).

Diets can also be modified to healthier options through consumer behaviours interventions. Most of these interventions are aimed at more nutritional education, the promotion of traditional cuisine and cooking skills, and increasing acceptability of food (e.g., fresh foods that meet quality and safety standards but not aesthetic ones) (Di Muro et al., 2016; Lee et al., 2002; Mazzocchi et al., 2014).

The interconnected causes of inequalities and the interactions across the different domains of the food system would probably make one single intervention to be insufficient, so that multiple interventions involving all relevant actors will be necessary to realize lasting changes. However, an intervention to address nutrition and health outcomes might have unintended effects outside the food system, so that considering possible synergies, trade-offs and negative effects from changes in diets becomes crucial (Ingram, 2011). The Health in All Policies approach could be useful on this task, as it has been used to address health determinants outside the field of health since 2006, reinforcing the potential impact on health of public policies across sectors and at different levels of governance (Puska & Ståhl, 2010).

1.2.4. Food system sustainability

Food systems have an impact on human health, but they also leave environmental footprints (Willett et al., 2019). For this reason, efforts are now concentrating on achieving healthy and sustainable diets through changes in the food system.

We can define a sustainable food system as the one that fulfils nutrition needs of local populations without threatening future generations or populations in other regions to meet their own needs (Serra-Majem, 2010). However, at present, the food system and thus our diet is one of the main causes for environmental pollution and resource demand (Ghosh et al., 2021).

Food production has different consequences on the geophysical environment –toxic emissions, air pollution, water consumption, etc.–, having animal-based foods a greater impact than plant-based foods (Carlsson-Kanyama & González, 2009; Poore & Nemecek, 2018). For instance, replacing beef and lamb consumption with pork, poultry and dairy products reduce ten times the green house emissions (GHE) per serving, although plant-based alternatives were associated with the greatest reductions in GHE (Aleksandrowicz et al., 2016; Ghosh et al., 2021). In addition, food processing also leaves important environmental footprints due to the use of energy and water and production of waste (Baker et al., 2020).

To achieve a sustainable diet, it is also important to promote the consumption of local food products given the environmental costs of transportation (Figure 4). Thus, the consumption of 1 kg domestic beef in a household represents automobile use of a distance of around 160 km (Carlsson-Kanyama & González, 2009).

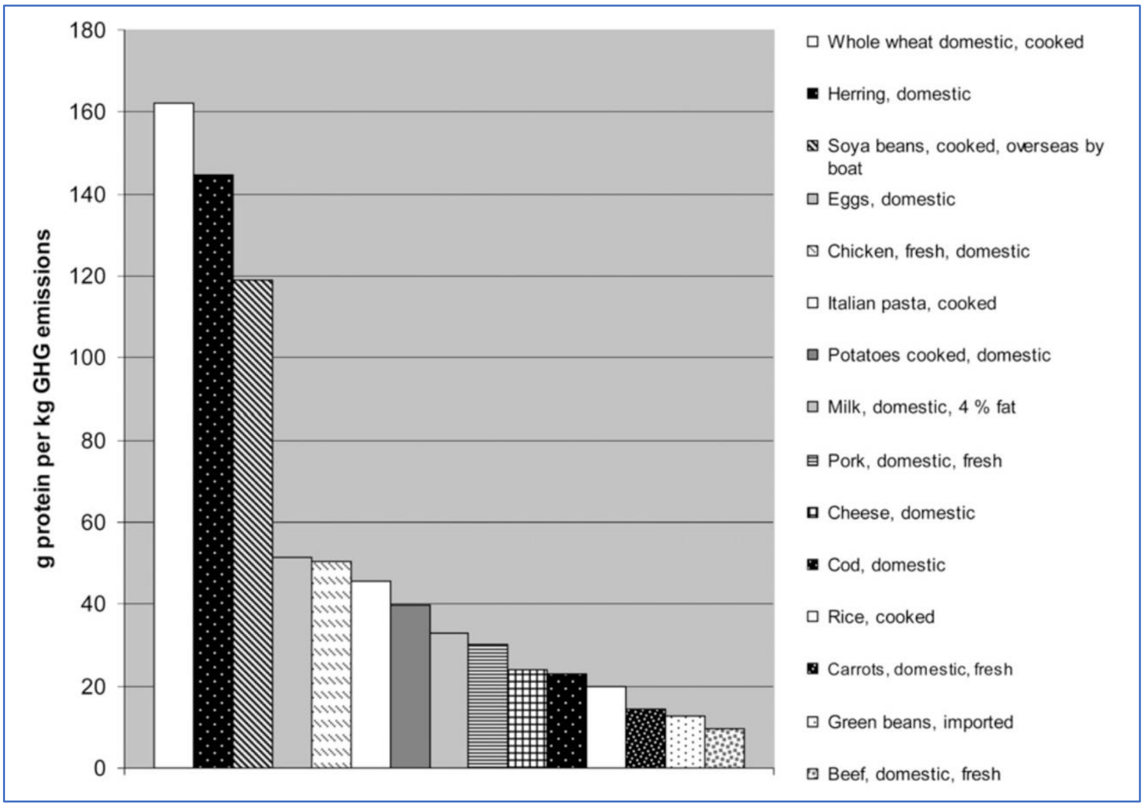

Figure 4. Protein content per amount of greenhouse gases (GHGs) emitted for various types of food. Source: Carlsson-Kanyama & González, 2009.

Sustainable diets not only produce benefits in our own health and the health of the planet but can also play a decisive role in climate change mitigation policies. Although climate change is already on the political agenda of international organisations and governments, in general, policy makers tend to focus on the energy sector to mitigate climate change, while livestock farming receive little attention despite accounting for 18.0% of greenhouse gas emissions and 80.0% of land used by humans. (Stehfest et al., 2009).

Balancing the promotion of human health with environmental protection presents some challenges, as will require substantial changes in the foods we produce and eat. However, traditional food culture can be used to promote sustainable and healthy behaviours. The Mediterranean diet, understood not only as a combination of foods, but also as a culture of how food is produced and processed, is an example of sustainability in itself and in its own biodiversity (Duchin, 2008; Gussow, 1995).

Public health nutrition offers a unique opportunity to foster healthier consumption patterns while ensuring production and access to diverse, safe, and sustainable foods, constituting a key aspect against climate change (Serra-Majem, 2010).

1.3. Public Health Economics

The main characteristic of economics as a science is that it deals with choice decisions in conditions of limited resources, where the decision-maker faces an opportunity cost for the alternatives not chosen. Robbins defined economics as the science of choice under conditions of scarcity (Robbins, 1935), and this definition is still valid today. Economics is thus the science of the trade-off, of the renunciation of some objectives in favor of others. In this sense, the objectives of a decision-maker or a society can be in conflict.

Microeconomics deals with the universe of decisions made by a person, household, or economic agent. Given their preferences –"utility"–, objectives –"profit maximization" (e.g., for a profit-making firm)– and constraints, the decision-maker is faced with a constrained maximization problem. Whatever the context of the decision, health or consumption or production, in most cases we can generically state the problem in this way. Through microeconomic analysis and with data from samples or populations of acting economic agents, economics contributes to understanding their behaviour. Many health policies are based on altering the conditions under which people act, by changing incentives, prices, or other elements of the environment. But for such policies to be justified, they need to be based on knowledge of human behaviour.

Many policies are not directed at individualizable persons, but at population groups, unlike policies directed at individuals such as scholarships or minimum income policies. An example is the Specific Supply Regime of the Canary Islands, which was designed to guarantee the local supply of imported essential goods in this outermost region of the

European Union (Consejería de Economía Industria Comercio y Cononcimiento del Gobierno de Canarias, 2018; Council Regulation (ECC) No 1601792 of 15 June 1992: Concerning Specific Measures for the Canary Islands with Regard to Certain Agricultural Products., 1992).

For their part, policies to support tourism cover a very broad range, from public promotion of the image of the destination, to subsidies for certain tourism projects or infrastructures. These are policies that seek local economic development thanks to the multiplier effect of the tourism sector, or its dragging capacity of other sectors of the economy. The Input-Output model allows to estimate the direct, indirect and induced impact of tourism on other sectors of the economy, and the Tourism Satellite Account (United Nations, 2001) is a standardized method for measuring the national economic contribution of tourism. In Spain, it has been estimated that the indirect and induced effects of tourism represent around 41.0% of the direct added value of the touristic production in 2019 (Cámara de Comercio de España, 2021). Therefore, it is a sector with a large multiplier.

On the other hand, public policies have a territorial substrate, both because many policies are embodied in public spending located in a certain place (e.g., construction of health centers, bicycle lanes or public parks) and because people are located in neighborhoods, and the distribution is not random. There are compositional effects –rich neighborhood, poor neighborhood– but there may also be causal effects –by living in a certain neighborhood without access to healthy food, children and adolescents in that neighborhood may have a higher risk of obesity–. Spatial economics has contributed to the knowledge of territorially based economic and social relations, analyzing phenomena such as spatial correlations or spill over between neighborhoods. Territorial equity is concerned with inequalities between people, according to socioeconomic or educational level, associated with the territory in which they live. The fact that in Barcelona city there is 9.6 years of difference in life expectancy at birth between the poor neighborhood of Vallbona (78.1) and the rich Pedralbes (87.7) is a bad indicator of territorial equity (Ayuntamiento de Barcelona, 2019).

In a broad sense, public health encompasses all areas of knowledge and disciplines that contribute to the understanding of the causes and effects related to the health of the population, while health economics brings its method and approach to this analysis.

Methodologically, economics has developed and standardized its own methods of economic evaluation to help in informed decisions on alternative actions with an impact on health, from clinical prevention to new health technologies. Cost-effectiveness, cost-utility, and cost-benefit analyses have become essential tools for health prioritization. But economics also provides a rigorous approach to the analysis of microdata, to understand human behaviour and to evaluate the impact of policies that directly affect people. Instrumental variables regression methods, which had already been used in econometrics since the mid-20th century to make causal inference with observational data, have gained new impetus when applied to public health in the last decades. Other more recent methods, such as regression discontinuity, differences in differences and matching, have joined the arsenal available for evaluating health policies. By its side, epidemiology has developed powerful tools to compare data from different populations, such as methods for standardizing event rates –mortality and others–.

1.4. The Canary Islands as a case study

The Canary Islands archipelago, a Spanish autonomous region located on the western coast of the African continent, is an outermost region of the European Union and, as such, it benefits from European Union law, rights and duties but with specific measures and derogations to help this region address the major challenges it faces due to its insular nature, remoteness, small size and difficult topography, which makes it an interesting case study (Consolidated Version of the Treaty on the Functioning of the European Union, 2012).

This archipelago is made up of eight inhabited islands with a total population of 2.2 million inhabitants in 2021, but with its two capital islands being home to 82.0% of the population. Despite of a gradual ageing of its population, demographic dynamics is of higher growth than other Spanish regions, partly due to its remarkable positive migratory balance, with an estimated 15.2% of relative population growth by 2037 (Instituto Nacional de Estadística, 2022c). However, it is the autonomous community with the greatest inequality in income distribution, with a value of 8.2 in the S20/S80 ratio in 2021(Instituto Nacional de Estadística, 2022b).

The islands economy is highly dependent on tourism, a sector that contributes 35.0% of regional GDP and 40.4% of employment, the Spanish autonomous region with the highest percentage of employment in the tourism sector. In 2019, received 15.1 million tourists (roughly 160 million overnights), of which 13.1 million came from abroad – especially from Europe in the Winter season–. In 2022, after the end of SARS-CoV-2 pandemic entry restrictions, it had practically recovered those numbers (Exceltur, 2021).

Its subtropical climate and its infrastructures and security at the level of a developed European country are the main attraction for inbound tourism (Instituto Canario de Estadística, 2022). As a consequence, the archipelago is a region of high population density with a considerable proportion of incoming tourists, that could result in changes in the health and well-being of the local population due to positive and negative externalities that must be identified, assessed and, where necessary, rectified.

The primary sector –agriculture, forestry, livestock and fishing– has been progressively reducing its share of GDP and barely represents 1.6% of GDP in 2021 (Instituto Nacional de Estadística, 2022a). Table 1 contains the information on the supply of food-related goods and services in the Canary Islands according to the Input-Output tables (Instituto Canario de Estadística, 2006). In 2005, imported products accounted for 32.9% of the supply of agricultural products and services, 7.0% of the supply of livestock products and services, 31.2% of fishing products and 6.7% of aquaculture products in the Canary Islands. As a results of the high dependence on imported food products, the this archipelago is still far from achieving food sovereignty. Thus, 17.3% of total expenditure on food establishments were made by tourists in 2016 (Rodríguez-Feijoo et al., 2018), so tourists' behaviours and preferences as consumers might be shaping the local food supply.

Table 1. Supply of products of the productive sectors related to food in the Canary Islands (in 1000€) and percentage of imports in 2005.

	Local production	Imported products	Imported products over the local supply
Products	Thousands of €		%
Agricultural products and services	559074	274105	32.9
Livestock products and services	170400	12865	7.0
Fishery products (exc. aquaculture)	71308	32328	31.2
Aquaculture products	16829	1208	6.7
Meat	71303	410306	85.2

Processed and canned fish	39518	121941	75.5
Processed and canned fruits and vegetables	52086	142282	73.2
Dairy products and ice creams	269072	157491	36.9
Mill products	57065	42014	42.4
Bread and biscuits	201651	99661	33.1
Chocolate and confectionery	27176	65301	70.6
Coffee, tea, and infusions	45.326	10829	19.3
Spices, sauces, and condiments	6922	24589	78.0
Processing of other food products	30807	225016	88.0
Distillation of alcoholic beverages and wine production	30941	163424	84.1
Beers and malt	138317	46750	25.3
Mineral water	295099	64486	17.9

Source: Instituto Canario de Estadística, 2006.

Data on the state of health, stands out the the Canarian population for its high rates of NCD such as obesity and type 2 diabetes. In 2020, the reported prevalence of type 2 diabetes (11.3%) and obesity (17.5%) in adult population was the highest and the fourth highest nationally in the Canary Islands (Ministerio de Sanidad, 2021). Thus, it is a region with rates of obesity (10.4%) and overweight (25.2%) in children above the national average and with a worrying upward trend in the prevalence of obesity in pregnant women since 1993 (Ministerio de Sanidad, 2018; Serra-Majem et al., 2022). Regarding mortality, the age-adjusted mortality rate from ischemic heart disease was one of the highest at the national level in 2020 (75.6 per 100,000 inhabitants), a major health problem in the Canary Islands. The mortality rates from certain diet-related cancers are also above the national average (Instituto de Información Sanitaria del Ministerio de Sanidad y Consumo, 2020).

1.5. Justification of this research

As stated previously, NCDs are a major health problem in the Canary Islands autonomous region, mainly because of the high mortality and morbidity rates due to obesity and overweight, diabetes and cardiovascular disease. Therefore, the study of food and diet, and its main determinants become of especial interest to prevent and control the development of NCDs.

This PhD dissertation aims to explore the association between diet and its determinants across the food system in the Canary Islands, with a holistic and integrative approach. In doing so, different statistical-econometric and epidemiological methods are used, working on the borderline between economics and public health.

There is a cross-cultural fertilization –acculturation process– from tourists to residents of health-related behaviours such as eating patterns (Reisinger, 2009; Romaguera et al., 2009; Tessier & Gerber, 2005), especially in small regions with a high population density (Reisinger, 2009). Proposed conceptual frameworks recognize the importance of the living environment on population diet (HLPE, 2017; Stok et al., 2017; Story et al., 2008; Swinburn et al., 2013) where tourism, as an external driver of local food supply, could have a significant effect (Cauchi et al., 2015; Doğan, 1989; Mak et al., 2012). Although the Canary Islands are a highly touristic region, the net effect of this acculturation process on the inhabitants' diet has not been studied so far. Chapter 1 of this PhD takes up the nutrition challenge, exploring the influence of tourism on the diet of the Canary Islands inhabitants.

Another conflict between contradictory social objectives is explored in Chapter 2. Due its remote and insular geographical situation, the Canary Islands region began receiving subsidies on selected food items to guarantee the regular supply of food inputs, at affordable prices, and to mitigate the additional costs arising from this condition. (Consejería de Economía Industria Comercio y Cononcimiento del Gobierno de Canarias, 2018; Council Regulation (ECC) No 1601792 of 15 June 1992: Concerning Specific Measures for the Canary Islands with Regard to Certain Agricultural Products., 1992). The list of subsidized foods includes some healthy and other obesogenic foods of high caloric value, such as sugar, butter, or fatty cheeses (Consejería de Economía Industria Comercio y Conocimiento del Gobierno de Canarias, 2018). This thesis dissertation explores the potential impact of removing this food subsidies on the obesity rates in the Canary Islands.

The third chapter focusses on the SES at the individual and neighbourhood level on two obesity determinants –diet and physical activity behaviour– in children, as these habits are heavily influenced by the living environment and could have adverse health effects throughout the life-course (Park et al., 2012; Swinburn et al., 2019). Specifically, the family SES, as an individual-level determinant, have an impact on children's habits and the built environment is also influenced by the neighbourhood SES (Popkin et al., 2005; Wang et al., 2007). Literature suggests that diet quality follows a socioeconomic pattern in children, where unhealthy diets are associated with low SES at the individual and neighbourhood level (Aranceta et al., 2003; Desbouys et al., 2020; Popkin et al., 2005; Wang et al., 2007). However, limited evidence is available in relation to physical activity in children and SES.

Given the high rates of obesity and overweight in children of the Canary Islands and the lack of previous studies, we decided to quantify the influence of socioeconomic inequalities at both individual and neighbourhood levels on these two healthy habits.

2. OBJECTIVES

2.1. General objective

The aim of this PhD is to explore food as a determinant of population health, focusing on the factors of the living environment in their intersection with the dietary habits of the Canary Islands inhabitants'.

2.2. Specific objectives

- To investigate whether tourist pressure affects Canary Islands inhabitants' adherence to the Mediterranean diet.

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

- To assess the effect of socioeconomic status at the individual and neighbourhood level on two health determinants –diet and leisure time physical activity– among the Canary Islands children and adolescents.

3. CHAPTER 1: Effect of tourism pressure on the Mediterranean diet.

3.1. Introduction

Tourism can have either a positive or a negative social effect on a host society. High tourist inflows could enhance a rapid change in local lifestyles (Akis, 2011; Goeldner & Brent Ritchie, 2009; Reisinger, 2009), affecting people's habits, daily routines, social lives, beliefs and values (Doğan, 1989). In small regions, especially if population density is high, cross-cultural tourism encounters are even more frequent and intense (De Kadt, 1979; Reisinger, 2009).

The most common tourist destination in the EU for non-residents is Spain (269 million nights spent in tourist accommodation establishments in 2015), and the Spanish region with the highest number of tourist overnight stays is the Canary Islands (94 million nights), which accounted for 3.4% of the total nights spent in the whole of the EU, 28 (Eurostat, 2017). In contrast to other tourist destinations, the inflow of tourists is stable all year round in these Spanish islands, as the main reason for traveling to this highly specialized sun and beach tourism destination is its mild subtropical climate (Instituto Canario de Estadística, 2017; Instituto Nacional de Estadística, 2017). Regarding tourism intensity, defined as the ratio of nights spent at a tourist accommodation establishment relative to the total permanent resident population of the area (Eurostat, n.d.), the Canary Islands recorded a ratio of 44219 nights spent per 1000 inhabitants in 2015 (Eurostat, 2017), which indicates that the magnitude of incoming tourists in relation to the population in this outermost region of the EU is quite remarkable. However, the Canarian population consider tourism as a resource and their support toward tourism has grown in the last years (Garau-Vadell et al., 2014, 2018).

As tourists are viewed as agents of change (Akis, 2011; De Kadt, 1979; Reisinger, 2009), and their food choices and preferences have a significant impact on local food supply (Mak et al., 2012), tourism could have an effect on the eating patterns of the inhabitants (Romaguera et al., 2008, 2009; Tessier & Gerber, 2005).

During the latter half of the 20th century, globalization drove food production and consumption (Bach-Faig, Berry, et al., 2011; Bermudez & Tucker, 2003; Lang, 1999; Oosterveer, 2006; Romaguera et al., 2008; Satia, 2010; Wilhelmina et al., 2010), resulting in a nutrition transition phenomenon worldwide that has led to the westernization of food consumption patterns (Bermudez & Tucker, 2003; Donini et al., 2015; Popkin et al., 2001; Popkin, 2004; Satia, 2010). In the Mediterranean countries, these eating pattern shifts could compromise both the beneficial effects in terms of the health and well-being of the Mediterranean dietary pattern (Álvarez-León et al., 2006; Ferro-Luzzi & Branca, 1995; Martínez-González et al., 2015; Romaguera et al., 2009) and its quality as a sustainable diet model (Donini et al., 2015; Sáez-Almendros et al., 2013). Although the geographical isolation of islands is seen as a barrier that retains cultural and social features, the nutrition transition has also been described in islands of the Mediterranean countries (Romaguera et al., 2009; Serra Majem et al., 2000; Tessier & Gerber, 2005). As these islands are frequent tourist destinations, the acculturation process, explained as the interaction of groups that fosters the exchange of cultural elements, might be an explanation for these findings (De Kadt, 1979; Reisinger, 2009; Satia, 2010). Thus, the external influence of the incoming tourists on eating patterns needs to be assessed while taking into account tourists' nationality, as substantial differences due to food cultures might be found (Mak et al., 2012; Pearce, 1995).

Therefore, the aim of the present study was to investigate whether tourist pressure affects Canary Islands inhabitants' adherence to the Mediterranean diet.

3.2. Methods

3.2.1. Dataset

Data were obtained from a health and lifestyle population-based survey conducted in the Canary Islands in 2009 and 2015 (Instituto Canario de Estadística, 2009a, 2015), which consisted of a stratified randomly selected sample of 5984 and 5703 individuals, respectively. Excluding subjects below the age of 16 or from the islands of La Gomera and El Hierro, where no tourist inflow data were available, the final sample consisted of 8303 individuals living in nine areas. Areas were defined as north, metropolitan and south of Gran Canaria and Tenerife, respectively, and the islands of Fuerteventura, Lanzarote, and La Palma.

3.2.2. Adherence to the Mediterranean Dietary Pattern

The survey assessed intake frequency of fresh fruits, vegetables, cereals, dairy products, fish, eggs, legumes, meat, cold meat and sausages, sweets and soft drinks as daily, three or more times per week, one to two times per week, less than once a week and never/almost never. A Mediterranean diet score was defined based on the Mediterranean diet eating pattern recommendations (Bach-Faig, Berry, et al., 2011): daily intake of vegetables, fruits, cereals and dairy products; intake of fish, legumes and eggs three times a week; intake of meat one to two times a week; intake of cold meat/sausages, sweets and soft drinks less than once a week. If the condition was met, 1 point was recorded for the category so that the final score ranged from 0 to 11.

3.2.3. Tourist Inflow

The arrival of tourists and their average stay, stratified by tourist nationality and area of destination, were obtained from the tourist expenditure database of the Canarian Institute for Statistics (Instituto Canario de Estadística, 2009b). Overnight stays were calculated and used as a proxy variable to measure tourist pressure.

3.2.4. Statistical Analysis

Descriptive characteristics were summarized by calculating means and standard deviations for continuous variables and frequencies for categorical values. As the variables were not normally distributed, medians and interquartile ranges are also reported. Multilevel linear regression analysis by restricted maximum likelihood estimation (Hox, 1995) was performed to examine the relationship between tourist pressure and the Mediterranean diet score. The year of the survey and other individual-level variables were tentatively included as fixed-effect variables. The Wald test was used to decide variable permanence in the model in a forward strategy of specification (explanatory variables that failed to reach a significantly better fit than the previous model were dropped). The final model can be written as:

$$y_{ij} = \beta_0 + \beta_1 x_{1j} + \beta_2 x_{2j} + \beta_3 x_{3j} + \beta_K z_{Kij} + u_j + e_{ij},$$

where y_{ij} is the Mediterranean diet score estimate for an individual i living in an area j; x_{1j}, x_{2j} and x_{3j} are, respectively, British, German and other nationalities tourists overnight stays in an area j; β, the fixed-effect regression coefficients; z_{Kij}, the fixed-effect individual explanatory variables (age, sex, civil status, educational level, BMI (Body Mass Index), smoking, alcohol, VAS-HRQL (Visual Analogue Scale-Health Related Quality of Life), employment status and year of survey); u_j, the area-level random error; and, e_{ij}, the individual-level random residual error. Subsequently, β_1, β_2, and β_3, coefficients were the focus of interest. Intra-class correlation was also estimated to measure the proportion of total variance attributable to differences between areas.

Statistical analyses were performed using the statistical software Stata/SE version 14 (Stata Corp., College Station, TX, USA).

3.3. Results

3.3.1. Participant Characteristics

Details regarding the age, sex, place of birth, civil status, educational level, BMI, smoking status, alcohol consumption, VAS-HRQL, labour market status, and survey cohort characteristics of the study population are shown in Table 2. The mean Mediterranean diet score slightly decreased between cohorts; 5.20 (SD 1.66) in 2009 and 5.17 (SD 1.84) in 2015.

3.3.2. Tourism Pressure

Tourist overnight stays increased for all nationalities in the nine areas studied except for Spanish tourists. The largest increase was for British tourists, mainly in the north and metropolitan areas of Gran Canaria and in the metropolitan area of Tenerife (732.23%, 402.59% and 360.02%, respectively). Table 3 describes the number of tourist overnight stays per year and the percent change in the rate, by nationality and area of destination.

3.3.3. Mediterranean Diet Score and Tourist Pressure by Nationality

Hierarchical regression analysis of the MD-score with tourist pressure is shown in Table 4. A significant negative association between the MD-score and British tourists pressure was observed ($\beta = -0.0064$, $p = 0.010$), which means that 10 million British tourists' overnight stays were associated with a 0.64 decrease in the MD-score in the local population. The opposite was observed with German tourist pressure, which showed a borderline significant positive association ($\beta = 0.0092$, $p = 0.042$). No significant relation was present with other tourist pressure. Between the 2009 and the 2015 cohort of participants, the MD-score significantly changed ($\beta = -0.0214$, $p = 0.005$). A significant relation was also present within all age groups; women; all education levels; moderate and heavy smokers; those who drink alcohol; those married; those employed or retired; those with pre-obesity, obesity class I or obesity class II; and with a VAS-HRQL score. The proportion of total variance attributable to differences between areas of destination was 4.21%.

Table 2. Characteristics of participants according to year of the survey.

Year of the survey		2009 *n* = 4160		2015 *n* = 4143	
Age, years	mean (SD)	47.63	(17.25)	50.79	(16.76)
	median (IQR)	45.00	(35.00-61.00)	50.00	(38.00-64.00)
Sex, women	*n* (%)	2436	(58.56)	2343	(56.55)
Place of birth, Spain	*n* (%)	3642	(87.55)	3776	(91.14)
Civil status	*n* (%)				
Single		1093	(26.27)	1225	(29.57)
Married		2014	(48.41)	1803	(43.52)
Widowed		376	(9.04)	448	(10.81)
Divorced / Separated		387	(9.30)	480	(11.59)
Registered partnership		290	(6.97)	187	(4.51)
Education level	*n* (%)				
Primary education		1442	(34.66)	1195	(28.96)
Lower secondary education		1012	(24.33)	974	(23.60)
Upper secondary education		1070	(25.72)	1236	(29.95)
Tertiary education		636	(15.29)	722	(17.49)
BMI, kg/m^2	mean (SD)	26.20	(4.83)	26.21	(4.71)
	median (IQR)	25.53	(22.84-35.09)	25.56	(23.01-28.73)
VAS-HRQL	mean (SD)	72.90	(20.57)	72.90	(20.22)
	median (IQR)	80.00	(60.00-90.00)	80.00	(60.00-90.00)
Smoking status	*n* (%)				
Non-smoker		2309	(55.85)	2352	(57.93)
Former smoker		678	(16.40)	683	(16.82)
Occasional smoker		95	(2.30)	104	(2.56)
Light smoker		228	(5.52)	242	(5.96)
Moderate smoker		669	(16.18)	569	(14.01)
Heavy smoker		155	(3.75)	110	(2.71)
Alcohol consumption, non-abstinent	*n* (%)	2391	(57.48)	2464	(59.47)
Labour market status	*n* (%)				
Active worker		1697	(40.79)	1634	(39.53)
Unemployed		868	(20.87)	892	(21.58)
Early retired / Retired		920	(22.12)	1097	(26.54)
Homemaker		431	(10.36)	267	(6.46)
Other		244	(5.87)	244	(5.90)

Smoking status was classified as: non-smoker; former smoker; occasional smoker (< 1 cigarette/day); light smoker (< 10 cigarettes/day); moderate smoker (10-20 cigarettes/day); heavy smoker (> 20 cigarettes/day). Abbreviations: SD, standard deviation; IQR, interquartile range; BMI, Body Mass Index; VAS-HRQL, Visual Analogue Scale-Health Related Quality of Life.

Table 3. Tourist overnight stays (thousands) and percent change in the rate between 2009 and 2015 by nationality and area of destination.

	British tourists			German tourists			Spanish tourists			Other tourists		
	2009	2015	variation	2009	2015	variation	2009	2015	variation	2009	2015	variation
	n	*n*	%	*n*	*n*	%	*n*	*n*	%	*n*	*n*	%
Area 1	2492.74	4152.54	66.59	6142.38	7570.61	23.25	952.10	844.11	-11.34	2569.89	4682.55	82.21
Area 2	11.73	97.59	732.23	60.74	111.49	83.55	157.38	469.62	198.40	53.90	262.98	387.89
Area 3	61.78	310.49	402.59	211.53	1439.55	580.54	883.97	1526.09	72.64	491.77	1673.80	240.36
Area 4	3773.80	4463.80	18.28	6416.24	6634.00	3.39	1521.97	1855.27	21.90	10686.58	15211.42	42.34
Area 5	5656.73	9644.41	70.49	2695.61	3030.59	12.43	1707.95	1674.11	-1.98	3274.67	5840.96	78.37
Area 6	147.03	232.58	58.19	690.23	756.99	9.67	364.51	329.52	-9.60	362.21	419.78	15.89
Area 7	514.42	535.90	4.18	1847.51	1859.73	0.66	1753.99	1256.14	-28.38	1116.54	1516.42	35.81
Area 8	91.79	422.26	360.02	132.04	177.68	34.57	389.25	420.65	8.07	158.72	351.52	121.47
Area 9	8909.67	12451.64	39.75	3107.74	3329.04	7.12	2075.20	1856.54	-10.54	8666.66	11591.69	33.75
Total	21659.69	32311.20	49.18	21304.02	24909.68	16.92	9806.31	10232.06	4.34	27380.94	41551.12	51.75

Table 4. Association between Mediterranean diet score (MD-score) and tourist pressure by nationality and characteristics of participants.

	MD-score *n* = 8303			
	β	95% CI		*p*
Tourist pressure*				
British tourists	-0.0064	-0.0112	-0.0015	0.010
German tourists	0.0092	0.0003	0.0181	0.042
Other tourists	-0.0001	-0.0047	0.0045	0.964
Cohort, 2015	-0.0214	-0.0365	-0.0063	0.005
Sex, women	0.2554	0 .1768	0.3340	< 0.001
Age, years				
16-24.9	Ref.	Ref.		Ref.
25-34.9	0.3515	0.1700	0.5330	< 0.001
35-49.9	0.7838	0.6062	0.9615	< 0.001
50-64.9	1.3337	1.1450	1.5223	< 0.001
65-79.9	1.5315	1.3119	1.7512	< 0.001
≥ 80	1.3910	1.1236	1.6585	< 0.001
Civil status				
Single	Ref.	Ref.		Ref.
Married	0.1327	0.0307	0.2346	0.011
Widowed	0.0733	-0.0911	0.2377	0.382
Divorced / Separated	0.0227	-0.1171	0.1625	0.750
Registered partnership	-0.1217	-0.2876	0.0442	0.151
Education level				
Primary education	Ref.	Ref.		Ref.
Lower secondary education	-0.1136	-0.2181	-0.0090	0.033
Upper secondary education	0.1176	0.0118	0.2233	0.029
Tertiary education	0.3335	0.2119	0.4551	< 0.001
BMI				
<18.5 (kg/m²)	-0.1631	-0.4132	0.0871	0.201
18.5-24.9 (kg/m²)	Ref.	Ref.		Ref.
25-29.9 (kg/m²)	-0.0995	-0.1812	-0.0177	0.017
30-34.9 (kg/m²)	-0.1634	-0.2754	-0.0514	0.004
35-39.9 (kg/m²)	-0.2135	-0.4133	-0.0137	0.036
≥ 40 (kg/m²)	-0.2936	-0.6110	0.0237	0.070
VAS-HRQL	0.0026	0.0007	0.0045	0.007
Smoking status				
Non-smoker	Ref.	Ref.		Ref.
Former smoker	0.0556	-0.0465	0.1577	0.286
Light smoker	-0.1073	-0.2423	0.0276	0.119
Moderate smoker	-0.4052	-0.5114	-0.2991	< 0.001
Heavy smoker	-0.6068	-0.8135	-0.4001	< 0.001
Alcohol consumption, non-abstinent	-0.2094	-0.2854	-0.1334	< 0.001
Labour market status				
Active worker	Ref.	Ref.		Ref.
Unemployed	0.0428	-0.0540	0.1395	0.386
Early retired / Retired	0.3164	0.1824	0.4505	< 0.001
Homemaker	0.2248	0.0728	0.3768	0.004
Other	0.2434	0.0596	0.4272	0.009

Tourist pressure*, Overnight stays/100,000 local population. Smoking status was classified as: non-smoker; former smoker; light smoker (< 10 cigarettes/day); moderate smoker (10-20 cigarettes/day); heavy smoker (> 20 cigarettes/day). Abbreviations: Ref., Reference category; BMI, Body Mass Index; VAS-HRQL, Visual Analogue Scale-Health Related Quality of Life.

3.4. Discussion

The literature has paid substantial attention to the identification of dietary patterns and their association with non-communicable diseases (Bamia, 2018; Serra-Majem et al., 2009). However, there are still gaps in the knowledge of factors contributing to changes in food habits. Proposed conceptual frameworks of eating behaviors (Cauchi et al., 2015; Stok et al., 2017; Story et al., 2008; Swinburn et al., 2013) recognize the importance of the environmental context in which people live , where tourism, as a driver of change on local food supply and inhabitants' lifestyles, could have an effect at the macro level food environment (Cauchi et al., 2015; Doğan, 1989; Mak et al., 2012).

Our results regarding a decrease in adherence to the Mediterranean diet are in agreement with other studies (Bach-Faig, Fuentes-Bol, et al., 2011; Serra Majem et al., 2000). Although the magnitude of the change is small between the Canarian population cohorts, this observation might be due to the relatively short period of time evaluated.

In accordance with previous studies, our results showed that the MD-score was higher in women (Costacou et al., 2003; Ferreira-Pêgo et al., 2017; Grosso et al., 2014; Sánchez-Villegas et al., 2002, 2003; Tong et al., 2018), older generations (Costacou et al., 2003; Ferreira-Pêgo et al., 2017; Sánchez-Villegas et al., 2002), non-smokers (Costacou et al., 2003; Tong et al., 2018) and higher educational levels (Bonaccio et al., 2014; Costacou et al., 2003; Marventano et al., 2018; Papadaki et al., 2015; Tong et al., 2018). An inverse correlation between BMI and adherence to the Mediterranean diet pattern was also found (Grosso et al., 2014). Although marital status was not related in some recent studies (Tong et al., 2018), our results are in agreement with others where those married show a higher MD-score than single subjects (Papadaki et al., 2015; Sánchez-Villegas et al., 2003). Though other studies assessed HRQL by using the SF-36 health survey (Henríquez Sánchez et al., 2012; Muñoz et al., 2009), a significantly positive association between adherence to the Mediterranean diet and VAS-HRQL was also found in the present study. In contrast to our results where those who reported alcohol consumption seem to have a lower MD-score, other studies have found a greater consumption of alcohol in the most adherent group (Ferreira-Pêgo et al., 2017; Grosso et al., 2014). However, these results might be expected as regular and moderate alcohol consumption was considered in those studies as a component of the MD-score.

The external influence of tourists on the inhabitants' eating patterns has been reported previously in some insular societies, where geographical isolation is seen as a barrier that retains food habits (Romaguera et al., 2009; Tessier & Gerber, 2005). The present study is original in our methods for quantifying the tourist pressure effect, which, as we hypothesized, varies depending on tourists' nationality. While British tourist pressure decreases inhabitants' adherence to the Mediterranean diet pattern, Germans have a positive significant influence on the MD-score. Additionally, our results provide insight on the magnitude of the tourist pressure effect, as 10 million British tourist overnight stays appear to have the same negative effect size as other commonly studied explanatory variables, such as heavy smokers ($\beta = -0.6068$), and almost double that of others such as obesity type I ($\beta = -0.2125$), whereas an equivalent German tourist pressure is nearly three times the positive effect of a tertiary education level ($\beta = 0.3335$). These results might be related to differences in food culture or the profile of tourists.

Overall, there were significant differences in the characteristics of tourists between nationalities. German tourists were older, with a higher professional qualification and a higher income level, whereas the proportion of women was higher among the British tourists; these differences remain in each of the cohorts (Instituto Canario de Estadística, 2017). Hence, in addition to age and sex, tourist socioeconomic status seems to play a role in the direction of the tourist pressure effect.

Regarding food culture, an upward trend of adherence to the Mediterranean diet pattern in some Non-Mediterranean countries, such as the United Kingdom, has previously been reported (da Silva et al., 2009). However, depending on which MD-score is used, adherence seems to be either lower in Germany than in the UK or with no remarkable differences between these two countries (da Silva et al., 2009; Fallaize et al., 2018). Thus, as with a large body of epidemiological studies, where diet quality, and, in particular, the traditional Mediterranean diet pattern, follows a socioeconomic gradient (Bonaccio et al., 2012; Gutiérrez-Fisac et al., 2012; Katsarou et al., 2010; Vlismas et al., 2009), differences in tourism pressure by nationality might be related to the socioeconomic level of the tourists.

Tourists are also likely to be influenced by local food culture when on vacation, consuming foods from the regions visited (Bessiere & Tibere, 2013). Although 71.48% of British and German tourists who visited the Canary Islands reported to have tasted local food (Instituto Canario de Estadística, 2017), there is no evidence about a major shift in their food habits during holidays. Furthermore, 17.30% of total expenditure on food establishments in this destination were made by tourists in 2016 (Rodríguez-Feijoo et al., 2018) so, consequently, food supply might be in line with food preferences of tourists.

This study has both limitations and strengths. The main advantage is its population-based design and the availability of tourist inflow data collected at a matching time. Moreover, the hierarchical model used considers the presence of clustering, which means non-independence of the outcome variable among people from the same area. Additionally, the study population is located in a highly touristic and ultraperipheral region, which makes findings relevant to other insular or continental environments that are important tourist destinations. On the other hand, as a repeated cross-sectional design is used, no individual change can be studied, though it is useful to examine changes over time at a population level. Furthermore, dietary assessment method with food frequency questionnaires (FFQ) are not free of systematic and random errors, and the use of scores to measure adherence is subject to chosen cut-off points, which may influence research findings. Nevertheless, FFQs and scores are valuable tools to evaluate epidemiological associations (Bach et al., 2006; Romaguera et al., 2009; Sáez-Almendros et al., 2013; Tong et al., 2018; Vyncke et al., 2013). Although tourist pressure seems to have an influence on adherence to the Mediterranean eating pattern, it is not possible to isolate the tourism effect from other external factors, such as urbanization, industrialization, food production and importation patterns, fast-food consumption or financial crisis (Bermudez & Tucker, 2003; Bonaccio et al., 2014; B. Popkin, 2004; Schröder et al., 2007).

3.5. Conclusions

In the present study, since tourist pressure has an effect on the inhabitants' adherence to the Mediterranean diet pattern, the importance of environmental context on diet is recognized. The socioeconomic level of tourists seems to be a determinant in the direction of the effect, driving food habits of the inhabitants. However, further investigation of other highly touristic destinations is needed to confirm these findings that could contribute to a shift in tourism and public health nutrition policies.

4. CHAPTER 2: Industrial policies that conflict with population health.

4.1. 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%) (World Health Organization, 2018). 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 (Afshin et al., 2017).

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 (Swinburn et al., 2011), so policy actions in these 2 domains need to be implemented to tackle obesity (Roberto et al., 2015). 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 (Cabrera Escobar et al., 2013; Eyles et al., 2012; Niebylski et al., 2015; Powell et al., 2013; Wright et al., 2017).

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 (Allcott et al., 2019).

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 (Hawkes et al., 2015). 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 (Elinder, 2005; Lloyd-Williams, 2008; Swinburn et al., 2011).

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 (Council Regulation (ECC) No 1601792 of 15 June 1992: Concerning Specific Measures for the Canary Islands with Regard to Certain Agricultural Products., 1992),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 (Aranceta et al., 2007; Aranceta, Pérez Rodrigo, et al., 2003).

For this purpose, we decided to focus on sugar and butter subsidies due to their association with long-term weight gain (Mozaffarian, 2019). Then we included cheese subsidies as a focus of interest, based not only on its possible association with overweight (Brouwer-Brolsma et al., 2018; Schwingshackl et al., 2016) 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– (Duarte-Alonso et al., 2009; Godenau et al., 2019).

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.

4.2. Methods

4.2.1. 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 (Briggs et al., 2013; Manyema et al., 2014; Scheelbeek et al., 2019; Schwendicke & Stolpe, 2017).

The analytical framework of the present study is shown in Figure 5.

4.2.2. 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 (Consejería de Economía Industria Comercio y Conocimiento del Gobierno de Canarias, 2018). 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 (Subdirección General de Comercialización y Relaciones Internacionales, 2018). As estimates for elasticity are generally local and not necessarily linear, price elasticity of demand (PED) values were obtained from a recent published study (Lasarte Navamuel et al., 2014) that estimates own-price elasticities for 10 aggregated food groups in Spain, including cheese, sugar, and oils and fats, by income –proxy of 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 (Cornelsen et al., 2015; Green et al., 2013).

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 (Briggs et al., 2013). Based on the findings of a previous local study (Conesa-Fontes & Chinea-Martín, 2012), 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.

4.2.3. 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 (Serra Majem et al., 2000). 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 (Ruiz et al., 2017). 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.

4.2.4. Weight Loss and Body Mass Index

To estimate change in weight we used energy balance equations (Swinburn et al., 2009) 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 (Manyema et al., 2014; Schwendicke & Stolpe, 2017). 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.

4.2.5. 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 (Instituto Canario de Estadística, 2015), 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 Annex I). From the baseline BMI in 2015 and its counterfactual, we estimated marginal obesity prevalence and the population potential attributable fraction (Gordis, 2000; Greenland & Drescher, 1993).

Frequency and sampling weights were considered in population-level estimates; the statistical software used to perform all statistical analyses was Stata/MP version 14.

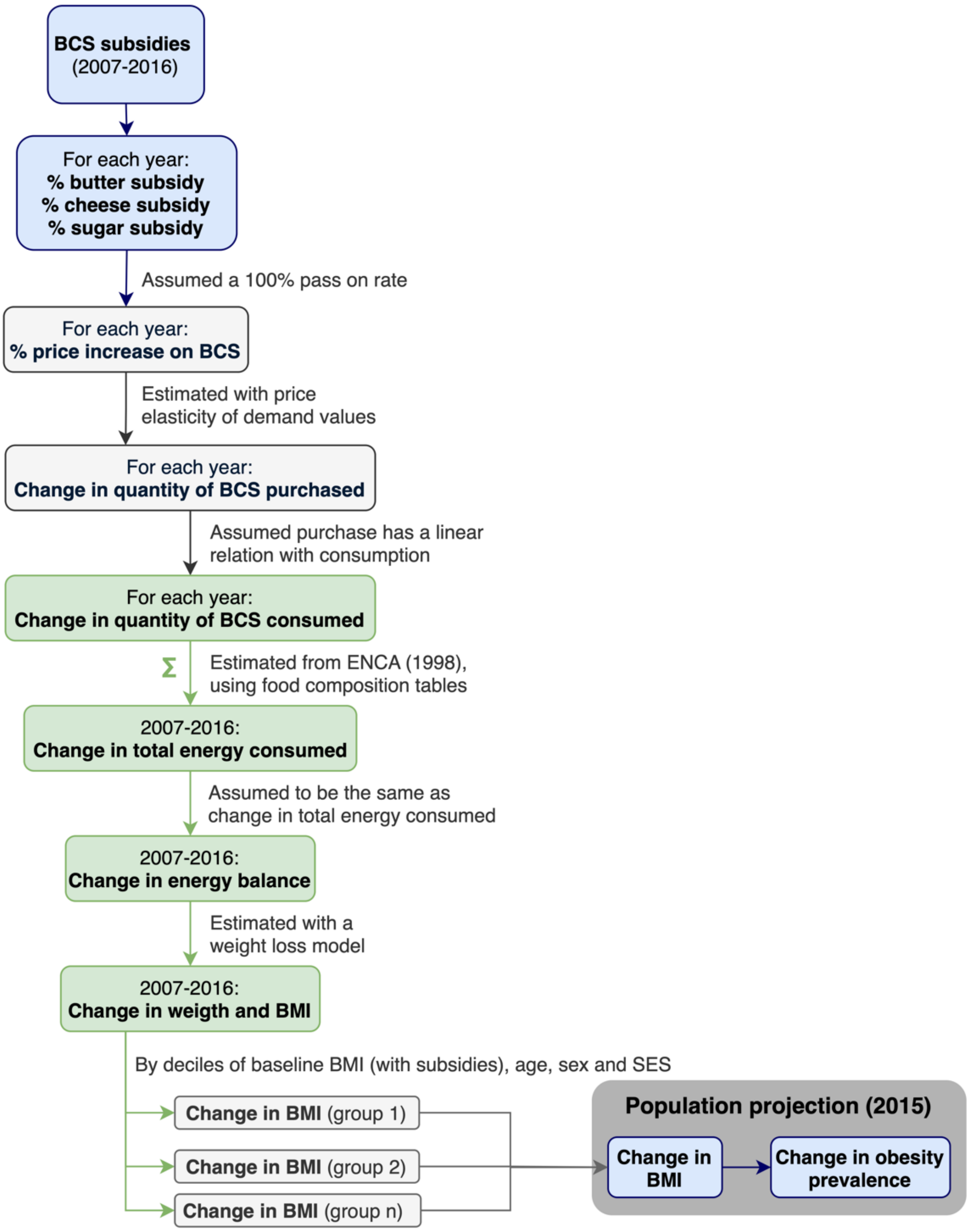

Figure 5. Analytical framework of the impact of removing butter, cheese, and sugar (BCS) subsidies on obesity prevalence.

ENCA: Canary Islands Nutrition Survey. SES: socioeconomic status.

4.3. Results

4.3.1. 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 5).

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 (Table 6-Table 7). The daily consumption of BCS at baseline by SES can be found in Table 8.

4.3.2. Change in Daily Energy Consumption and BMI

Table 9 presents the estimated changes in energy consumption when removing BCS subsidies, by age group and sex. The average 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 (Table 10-Table 12).

4.3.3. Impact on Obesity Prevalence

Projected changes in the prevalence of obesity by age group, sex, and SES are shown in Table 13-Table 14. 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 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).

4.3.4. 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 (Table 15-Table 20). 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).

Table 5. 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									

BCS: butter, cheese, and sugar. Cheese A: yellow and cream cheeses. Cheese B: Idiazabal, Manchego and Manouri cheeses. Municipality 1: more than 100000 inhabitants. Municipality 2: 10000-100000 inhabitants. Municipality 3: less than 10000 inhabitants. PED: Price elasticity of demand.

Table 6. Daily consumption (g/capita) of BCS at baseline by age group and sex.

		Butter		Cheese		Sugar	
		Male	Female	Male	Female	Male	Female
Age (years)	n	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: butter, cheese, and sugar. SD: standard deviation.

Table 7. Daily consumption (g/capita) of food groups with added sugar at baseline by age group and sex.

	Cereals with AD		**Confectionery**		**Dairy with AD**		**SSB**		**Fats, oils and sauces with AD**	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Age (years)	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: added sugar. SBB: sweetened beverages. SD: standard deviation.

Table 8. Daily consumption (g/capita) of BCS at baseline by sex and SES.

		Butter		Cheese		Sugar	
		Male	Female	Male	Female	Male	Female
SES	n	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Low	676	2.14 (4.69)	2.07 (4.60)	61.29 (64.57)	52.78 (56.81)	20.53 (20.81)	17.33 (17.52)
Medium	373	1.84 (5.52)	1.79 (4.41)	50.87 (54.14)	81.78 (92.55)	17.53 (19.64)	17.54 (19.95)
High	174	2.33 (5.52)	1.77 (3.84)	68.01 (67.33)	59.81 (64.28)	15.04 (15.17)	14.46 (14.04)

BCS: butter, cheese and sugar. SES: socioeconomic status. SD: standard deviation.

Table 9. 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; -87.63)	-87.99 (-101.73; -74.25)	-50.94 (-62.46; -39.43)	-49.88 (-60.14; -39.61)	-152.14 (-168.70; -135.58)	-137.87 (-156.60; -119.15)
25-34	252	-90.76 (-104.31; -77.22)	-79.72 (-91.17; -68.26)	-52.48 (-61.48; -43.47)	-50.96 (-58.92; -42.99)	-143.24 (-161.18; -125.29)	-130.67 (-145.63; -115.72)
35-44	162	-74.51 (-86.70; -62.32)	-82.59 (-93.98; -71.20)	-52.82 (-61.04; -44.60)	-53.69 (-62.45; -44.93)	-127.33 (-141.43; -113.24)	-136.28 (-151.58; -120.98)
45-54	247	-85.77 (-102.89; -68.65)	-61.28 (-70.53; -52.03)	-52.33 (-60.81; -43.85)	-54.91 (-63.56; -46.26)	-130.10 (-157.21; -118.98)	-116.19 (-129.13; -103.25)
55-64	217	-63.51 (-74.32; -52.70)	-57.15 (-65.21; -49.08)	-43.71 (-51.86; -35.55)	-49.40 (-60.72; -38.09)	-107.22 (-120.74; -93.70)	-106.55 (-119.66; -93.44)
65-75	176	-55.94 (-67.46; -44.42)	-52.33 (-62.61; -42.06)	-42.92 (-53.29; -32.54)	-49.21 (-59.84; -38.57)	-98.86 (-115.66; -82.06)	-101.54 (-116.42; -86.66)
All	1348	-79.50 (-85.08; -73.92)	-70.68 (-75.16 -66.20)	-49.62 (-53.36; -45.87)	-51.64 (-55.49; -47.80)	-129.11 (-135.98; -122.25)	-122.33 (-128.46; -116.19)

BCS: butter, cheese, and sugar. 95%CI: 95% confidence interval. *PED taken from Lasarte et al.

Table 10. Change of daily energy consumption (kcal/capita) when removing CBS subsidies, by sex and SES.

		Sugar subsidy*		**Butter and Cheese subsidies***		**BCS subsidies***	
		Male	Female	Male	Female	Male	Female
SES	n	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)
Low	676	-93.18 (-102.23; -84.14)	-76.99 (-83.45; -70.53)	-53.79 (-59.50; -48.07)	-47.52 (-52.29; -42.74)	-146.97 (-157.96; -135.99)	-124.51 (-132.83; -116.19)
Medium	373	-70.36 (-79.98; -60.75)	-66.49 (-75.80; -57.19)	-41.72 (-47.83; -35.61)	-61.72 (-71.10; -52.33)	-112.08 (-123.25; -100.92)	-128.21 (-142.23; -114.20)
High	174	-63.93 (-74.44; -53.43)	-55.10 (-65.00; -45.19)	-55.77 (-66.37; -45.18)	-48.80 (-59.23; -38.38)	-119.71 (-135.12; -104.29)	-103.90 (-118.65; -89.15)

BCS: butter, cheese, and sugar. SES: socioeconomic status. 95%IC: 95% confidence interval. *PED taken from Lasarte et al.

Table 11. Baseline obesity prevalence and mean BMI (m2/Kg) in 2015 population, by sex and SES.

			Baseline obesity prevalence		Baseline BMI	
			Male (N= 682653‡)	Female (N= 850386‡)	Male (N= 682653‡)	Female (N= 850386‡)
SES	N	n	%	%	Mean (SD)	Mean (SD)
Low	355375‡	989	20.82	21.45	26.93 (4.70)	26.38 (5.51)
Medium	916847‡	2490	20.98	17.20	26.90 (4.28)	25.77 (4.94)
High	260817‡	676	11.25	9.10	25.72 (3.69)	24.30 (3.91)
All	1533039‡	4155	19.21	16.91	26.70 (4.28)	25.68 (4.98)

SES: socioeconomic status. N: target population in 2015. ‡Estimated target population characteristics by using survey weights.

Table 12. Change in mean BMI (m2/Kg) when removing BCS subsidies in 2015 population, by age group and sex.

			Sugar subsidy*		Butter and Cheese subsidies*		BCS subsidies*	
			Male	Female	Male	Female	Male	Female
Age (years)	N	n	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)	Mean (95%IC)
18-24	120353‡	301	-0.067 (-0.072; -0.062)	-0.059 (-0.063; -0.055)	-0.031 (-0.035; -0.028)	-0.031 (-0.033; -0.029)	-0.099 (-0.105; -0.092)	-0.90 (-0.095; -0.085)
25-34	218497‡	553	-0.054 (-0.056; -0.051)	-0.061 (-0.064; -0.058)	-0.031 (-0.032; -0.028)	-0.042 (-0.043; -0.041)	-0.084 (-0.087; -0.081)	-0.103 (-0.106; -0.100)
35-44	327922‡	876	-0.053 (-0.055; -0.051)	-0.066 (-0.069; -0.063)	-0.038 (-0.039; -0.036)	-0.039 (-0.041; -0.038)	-0.091 (-0.093; -0.089)	-0.105 (-0.109; -0.102)
45-54	342483‡	918	-0.059 (-0.062; -0.057)	-0.053 (-0.055; -0.050)	-0.039 (-0.041; -0.037)	-0.052 (-0.054; -0.049)	-0.098 (-0.101; -0.095)	-0.104 (-0.108; -0.100)
55-64	290596‡	822	-0.053 (-0.056; -0.050)	-0.059 (-0.061; -0.056)	-0.037 (-0.040; -0.034)	-0.052 (-0.055; -0.050)	-0.090 (-0.093; -0.087)	-0.111 (-0.115; -0.107)
65-75	233188‡	685	-0.046 (-0.048; -0.043)	-0.045 (-0.047; -0.043)	-0.036 (-0.038; -0.034)	-0.051 (-0.053; -0.049)	-0.082 (-0.084; -0.079)	-0.096 (-0.098; -0.093)
All	1533039‡	4155	-0.054 (-0.056; -0.053)	-0.057 (-0.058; -0.056)	-0.036 (-0.037; -0.035)	-0.046 (-0.047; -0.045)	-0.091 (-0.092; -0.089)	-0.103 (-0.104; -0.101)

BCS: butter, cheese, and sugar. 95%IC: 95% confidence interval. *PED taken from Lasarte et al. ‡Estimated target population characteristics by using survey weights.

Table 13. 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	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)
18-24	301	0.000 (-0.282; 0.282)	0.000 (-0.339; 0.339)	0.000 (-0.282; 0.282)	0.000 (-0.339; 0.339)	0.000 (-0.282; 0.282)	0.000 (-0.339; 0.339)
25-34	553	0.000 (-0.290; 0.290)	0.000 (-0.272; 0.272)	0.000 (-0.290; 0.290)	0.000 (-0.272; 0.272)	-0.597 (-0.884; -0.311)	-0.298 (-0.569; -0.027)
35-44	876	0.000 (-0.285; 0.285)	-0.349 (-0.561; -0.137)	0.000 (-0.285; 0.285)	0.000 (-0.213; 0.213)	-0.721 (-1.004; -0.438)	-0.478 (-0.689; -0.267)
45-54	918	-0.427 (-0.693; -0.160)	0.000 (-0.217; 0.217)	-0.427 (-0.693; -0.160)	0.000 (-0.217; 0.217)	-1.122 (-1.387; -0.858)	-0.695 (-0.909; -0.480)
55-64	822	-0.186 (-0.516; 0.144)	-0.598 (-0.901; -0.294)	0.000 (-0.331; 0.331)	0.000 (-0.305; 0.305)	-0.770 (-1.100; -0.441)	-0.828 (-1.130; -0.525)
65-75	685	-0.387 (-0.752; -0.022)	-0.698 (-1.029; -0.368)	-0.387 (-0.752; -0.022)	0.000 (-0.332; 0.332)	-1.066 (-1.429; -0.703)	-0.808 (-1.138; -0.478)
All	4155	-0.189 (-0.320; -0.057)	-0.288 (-0.400; -0.175)	-0.151 (-0.282; -0.019)	0.000 (-0.112; 0.112)	-0.805 (-0.935; -0.674)	-0.573 (-0.685; -0.461)

BCS: butter, cheese, and sugar. 95%CI: 95% confidence interval. *PED taken from Lasarte et al.

Table 14. Marginal difference in obesity prevalence (percentage points) when removing BCS subsidies in 2015, by sex and SES.

		Sugar subsidy*		**Butter and Cheese subsidies***		**BCS subsidies***	
		Male	Female	Male	Female	Male	Female
SES	n	percent points (95%IC)	percent points (95%IC)	percent points (95%IC)	percent points (95%IC)	percent points (95%IC)	percent points (95%IC)
Low	989	0.183 (-0.127; 0.493)	-1.303 (-1.537; -1.068)	0.183 (-0.127; 0.493)	-0.228 (-0.465; 0.009)	-0.514 (-0.822; -0.206)	-1.544 (-1.778; -1.310)
Medium	2490	-0.300 (-0.471; -0.128)	0.000 (-0.150; 0.150)	-0.240 (-0.411; -0.068)	0.000 (-0.150; 0.150)	-1.013 (-1.183; -0.842)	-0.338 (-0.487; -0.189)
High	676	0.000 (-0.252; 0.252)	0.000 (-0.217; 0.217)	0.000 (-0.252; 0.252)	0.000 (-0.217; 0.217)	-0.183 (-0.434; 0.067)	-0.160 (-0.377; 0.056)

BCS: butter, cheese, and sugar. SES: socioeconomic status. 95%IC: 95% confidence interval. *PED taken from Lasarte et al.

Table 15. Change of daily energy consumption (kcal/capita) when removing sugar subsidies, by age group and sex (sensitivity analysis).

		Sugar subsidy (PED*)		Sugar subsidy (PED & CPE‡)	
		Male	Female	Male	Female
Age (years)	n	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
18-24	194	-80.91 (-92.26; -69.57)	-70.06 (-81.48; -58.63)	-66.37 (-77.33; -55.41)	-56.16 (-66.94; -45.38)
25-34	252	-71.56 (-82.36; -60.76)	-65.16 (-75.07; -55.24)	-58.37 (-68.81; -47.93)	-53.03 (-62.23; -43.83)
35-44	162	-61.14 (-71.53; -50.75)	-68.89 (-78.52; -59.26)	-46.90 (-56.90; -36.90)	-53.92 (-62.95; -44.90)
45-54	247	-71.17 (-85.55; -56.80)	-51.42 (-59.28; -43.57)	-55.20 (-68.61; -41.80)	-38.48 (-45.76; -31.21)
55-64	217	-53.75 (-63.09; -44.41)	-47.31 (-54.17; -40.45)	-38.59 (-47.19; -29.99)	-32.89 (-39.20; -26.58)
65-75	176	-47.69 (-57.60; -37.78)	-43.09 (-51.63; -34.56)	-33.62 (-42.70; -24.53)	-31.10 (-38.90; -23.29)
All	1348	-64.97 (-69.60; -60.33)	-58.19 (-61.97 -54.41)	-50.47 (-54.87; -46.07)	-44.74 (-48.26; -41.21)

CPE: Cross-price Elasticity of Demand. PED: Price Elasticity of Demand. 95%CI: 95% confidence interval. *Considering a PED of -0.56, taken from Green et al. ‡Considering CPE between sugar and other food groups (cereals=0.048, dairy=0.057, fruits & vegetables=0.060, meat=0.049), taken from Cornelsen et al.

Table 16. Change of daily energy consumption (kcal/capita) when removing butter and cheese subsidies, by age group and sex (sensitivity analysis).

		Butter and Cheese subsidy (PED*)		Butter and Cheese subsidies (PED & CPE‡)	
		Male	Female	Male	Female
Age (years)	n	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
18-24	194	-37.95 (-46.56; -29.34)	-36.21 (-43.95; -28.47)	-37.89 (-46.49; -29.30)	-36.21 (-43.96; -28.47)
25-34	252	-38.90 (-45.88; -31.93)	-39.25 (-45.64; -32.87)	-38.81 (-45.78; -31.84)	-39.25 (-45.63; -32.86)
35-44	162	-41.22 (-47.68; -34.77)	-42.37 (-49.58; -35.15)	-41.18 (-47.63; -34.74)	-42.38 (-49.60; -35.17)
45-54	247	-41.27 (-47.96; -34.57)	-44.43 (-51.55; -37.30)	-41.25 (-47.97; -34.54)	-44.46 (-51.59; -37.33)
55-64	217	-36.14 (-43.09; -29.19)	-41.18 (-51.14; -31.22)	-36.13 (-43.09; -29.17)	-41.19 (-51.14; -31.24)
65-75	176	-36.53 (-45.49; -27.57)	-40.76 (-49.46; -32.06)	-36.57 (-45.55; -27.58)	-40.80 (-49.50; -32.10)
All	1348	-38.84 (-41.81; -35.87)	-40.97 (-44.15; -37.79)	-38.81 (-41.78; -35.84)	-40.98 (-44.16; -37.81)

CPE: Cross-price Elasticity of Demand. PED: Price Elasticity of Demand. 95%CI: 95% confidence interval. *Considering a PED of -0.42 for butter and a PED of -0.60 for cheese, taken from Green et al. ‡Considering CPE between cheese and other food groups (cereals=0.039, fish=-0.032, fruits & vegetables=-0.030).

Table 17. Change of daily energy consumption (kcal/capita) when removing BCS subsidies, by age group and sex (sensitivity analysis).

		BCS subsidy (PED*)		BCS subsidies (PED & CPE‡)	
		Male	Female	Male	Female
Age (years)	n	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
18-24	194	-118.86 (-131.81; -105.91)	-106.27 (-121.16; -91.37)	-104.27 (-116.55; -91.99)	-92.37 (-106.38; -78.35)
25-34	252	-110.46 (-124.32; -96.60)	-104.41 (-117.12; -91.69)	-97.18 (-110.60; -83.76)	-92.27 (-104.13; -80.42)
35-44	162	-102.37 (-113.73; -91.00)	-111.25 (-123.92; -98.58)	-88.08 (-98.92; -77.25)	-96.30 (-108.21; -84.40)
45-54	247	-112.44 (-128.13; -96.76)	-95.85 (-106.59; -85.11)	-96.46 (-111.20; -81.71)	-82.94 (-92.89; -72.99)
55-64	217	-89.89 (-101.42; -78.35)	-88.49 (-99.88; -77.11)	-74.72 (-85.29; -64.14)	-74.08 (-84.77; -63.38)
65-75	176	-84.22 (-98.59; -69.85)	-83.85 (-96.08; -71.63)	-70.19 (-83.31; -57.06)	-71.89 (-83.45; -60.34)
All	1348	-103.81 (-109.31; -98.31)	-99.16 (-104.24; -94.08)	-89.28 (-94.48; -84.08)	-85.72 (-90.48; -80.95)

CPE: Cross-price Elasticity of Demand. PED: Price Elasticity of Demand. 95%CI: 95% confidence interval. *Considering a PED of -0.42 for butter and a PED of -0.60 for cheese, taken from Green et al. ‡Considering CPE taken from Cornelsen et al. (Sugar: cereals=0.048, dairy=0.057, fruits & vegetables=0.060, meat=0.049; Cheese: cereals=0.039, fish=-0.032, fruits & vegetables=-0.030).

Table 18. Change in mean BMI (m2/Kg) when removing BCS subsidies in 2015 population, by age group and sex (sensitivity analysis).

		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	301	-0.047 (-0.052; -0.043)	-0.039 (-0.043; -0.036)	-0.023 (-0.026; -0.021)	-0.023 (-0.025; -0.022)	-0.071 (-0.076; -0.066)	-0.063 (-0.067; -0.059)
25-34	553	-0.036 (-0.037; -0.033)	-0.041 (-0.044; -0.039)	-0.024 (-0.025; -0.023)	-0.033 (-0.034; -0.032)	-0.059 (-0.061; -0.057)	-0.074 (-0.077; -0.072)
35-44	876	-0.035 (-0.037; -0.033)	-0.044 (-0.047; -0.042)	-0.031 (-0.032; -0.029)	-0.033 (-0.034; -0.032)	-0.065 (-0.067; -0.064)	-0.077 (-0.080; -0.074)
45-54	918	-0.040 (-0.042; -0.037)	-0.033 (-0.035; -0.031)	-0.033 (-0.035; -0.031)	-0.043 (-0.045; -0.041)	-0.072 (-0.075; -0.070)	-0.076 (-0.079; -0.073)
55-64	822	-0.033 (-0.036; -0.031)	-0.035 (-0.037; -0.033)	-0.031 (-0.034; -0.029)	-0.045 (-0.047; -0.042)	-0.065 (-0.067; -0.062)	-0.080 (-0.084; -0.077)
65-75	685	-0.027 (-0.029; -0.025)	-0.025 (-0.026; -0.023)	-0.031 (-0.032; -0.029)	-0.044 (-0.045; -0.042)	-0.058 (-0.060; -0.056)	-0.068 (-0.070; -0.066)
All	4155	-0.035 (-0.036; -0.034)	-0.036 (-0.037; -0.035)	-0.030 (-0.031; -0.029)	-0.038 (-0.039; -0.037)	-0.065 (-0.066; -0.064)	-0.074 (-0.076; -0.073)

BCS: butter, cheese, and sugar. 95%CI: 95% confidence interval. *PED and CPE taken from Green et al. and Cornelsen et al., respectively.

Table 19. Marginal difference in obesity prevalence (percentage points) when removing BCS subsidies in 2015, by age group and sex (sensitivity analysis).

		Sugar subsidy*		Butter and Cheese subsidies*		BCS subsidies*	
		Male	Female	Male	Female	Male	Female
Age (years)	n	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)
18-24	301	0.000 (-0.282; 0.282)	0.000 (-0.339; 0.339)	0.000 (-0.282; 0.282)	0.000 (-0.339; 0.339)	0.000 (-0.282; 0.282)	0.000 (-0.339; 0.339)
25-34	553	0.000 (-0.290; 0.290)	0.000 (-0.272; 0.272)	0.000 (-0.290; 0.290)	0.000 (-0.272; 0.272)	0.000 (-0.290; 0.290)	0.000 (-0.272; 0.272)
35-44	876	0.000 (-0.285; 0.285)	-0.299 (-0.511; -0.087)	0.000 (-0.285; 0.285)	0.000 (-0.213; 0.213)	0.000 (-0.285; 0.285)	-0.349 (-0.561; -0.137)
45-54	918	-0.427 (-0.693; -0.160)	0.000 (-0.217; 0.217)	-0.427 (-0.693; -0.160)	0.000 (-0.217; 0.217)	-0.427 (-0.693; -0.160)	-0.600 (-0.816; -0.385)
55-64	822	-0.089 (-0.419; 0.242)	0.000 (-0.305; 0.305)	0.000 (-0.331; 0.331)	0.000 (-0.305; 0.305)	-0.248 (-0.578; 0.082)	-0.598 (-0.901; -0.294)
65-75	685	0.000 (-0.366; 0.366)	-0.698 (-1.029; -0.368)	-0.387 (-0.752; -0.022)	0.000 (-0.332; 0.332)	-0.387 (-0.752; -0.022)	-0.808 (-1.138; -0.478)
All	4155	-0.112 (-0.244; 0.020)	-0.171 (-0.284; -0.058)	-0.151 (-0.282; -0.019)	0.000 (-0.113; 0.113)	-0.201 (-0.333; -0.070)	-0.441 (-0.553; -0.328)

BCS: butter, cheese, and sugar. 95%CI: 95% confidence interval. *PED and CPE taken from Green et al. and Cornelsen et al., respectively.

Table 20. Marginal difference in obesity prevalence (percentage points) when removing CBS subsidies in 2015, by sex and SES (sensitivity analysis).

		Sugar subsidy*		**Butter and Cheese subsidies***		**BCS subsidies***	
		Male	Female	Male	Female	Male	Female
SES	n	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)	percent points (95%CI)
Low	989	0.000 (-0.304; 0.304)	-0.867 (-1.102; -0.630)	0.183 (-0.127; 0.493)	-0.228 (-0.465; 0.008)	0.000 (-0.304; 0.304)	-1.099 (-1.337; -0.861)
Medium	2490	-0.268 (-0.440; -0.096)	0.000 (-0.150; 0.150)	-0.240 (-0.411; -0.068)	0.000 (-0.150; 0.150)	-0.268 (-0.440; -0.096)	-0.267 (-0.416; -0.117)
High	676	-0.183 (-0.434; 0.067)	0.000 (-0.217; 0.217)	0.000 (-0.252; 0.252)	0.000 (-0.217; 0.217)	-0.183 (-0.434; 0.067)	0.000 (-0.217; 0.217)

BCS: butter, cheese, and sugar. SES: socioeconomic status. 95%CI: 95% confidence interval. *PED and CPE taken from Green et al. and Cornelsen et al., respectively.

4.4. 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 (Cornelsen et al., 2015). 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 (Lucan & DiNicolantonio, 2015). 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 (Dreher & Ford, 2020; Schwingshackl et al., 2015).

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 (Scheelbeek et al., 2019). 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 (Härkänen et al., 2014). 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 (Niebylski et al., 2015; Wright et al., 2017). 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 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 (Schwingshackl et al., 2016).

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 (Cabrera Escobar et al., 2013; Eyles et al., 2012; Niebylski et al., 2015; Powell et al., 2013; Wright et al., 2017).

Because products known for their positive health effects –such as fruits and olive oil (Bach-Faig, Berry, et al., 2011; Sacks et al., 1999)– 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 (Härkänen et al., 2014; Manyema et al., 2016), 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 (Instituto de Información Sanitaria del Ministerio de Sanidad Consumo y Bienestar Social, 2017), 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 (Goettler et al., 2017).

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 (A. D. M. Briggs et al., 2017).

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 (Shumow, 2014). 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 (Godenau et al., 2019). 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 (Roberto et al., 2015; Waterlander et al., 2013).

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 (Council Regulation (ECC) No 1601792 of 15 June 1992: Concerning Specific Measures for the Canary Islands with Regard to Certain Agricultural Products., 1992). 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 food system governance, where environmental, social, and eco- nomic issues are integrated, there is an inherent need to consider the food system as a whole (Godenau et al., 2019; Hernández et al., 2018).

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 low-SES families are more sensitive to price change (Mytton et al., 2012; Powell & Chaloupka, 2009; Smed et al., 2007), 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 (Duarte & Barreira, 1998; Gould et al., 1991), 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 (Swinburn et al., 2009) based on change in total energy consumed, which might not fully reflect mechanisms of weight loss (Camacho & Ruppel, 2017). 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 (Manyema et al., 2014; Schwendicke & Stolpe, 2017).

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.

4.5. 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.

5. CHAPTER 3: Socioeconomic disparities in diet and physical activity in children.

5.1. Introduction

It is well known that diet and movement behaviours play an important role in the prevention of several chronic diseases, among which obesity is a major public health concern globally in both children and adults (World Health Organization, 2016). Worldwide, 671 million adults and 124 million children (5-19 years) were obese in 2016 (NCD Risk Factor Collaboration (NCD-RisC), 2017), and will continue rising during the next decade, reaching 254 million children with obesity (World Health Organization, 2021a). European countries are no exception, around 25-30% of children are overweight or obese, with the highest levels found in the Mediterranean basin (NCD Risk Factor Collaboration (NCD-RisC), 2017; World Health Organization, n.d.). In Spain, 18.3% and 10.3% of children (2-17 years) were overweight and obese in 2017, respectively, being the Canary Islands one of the Spanish autonomous regions with the highest prevalence of overweight children (25.2%) (Ministerio de Sanidad, 2018).

As obesity state carries over from childhood into adulthood, and being an overweight child is also associated with adverse health effects throughout the life-course, prevention strategies should focus on this life stage (Craigie et al., 2011; Park et al., 2012). Therefore, unbalanced diet and lack of physical activity, as leading global risks to health, have long been objects of interest in children.

The World Health Organization European Childhood Obesity Study, carried out in 37 European countries, showed a synergistic positive effect on health of having high levels on physical activity and having high fruit and vegetable intakes, combined with limited screen time use and low consumption of sugar-sweetened beverages (SSB). However, high levels of screen-time behaviours could mask the potential role of physical activity and healthy diet on reducing the obesogenic risk (Bel-Serrat et al., 2019).

Improving healthy eating and physical activity behaviour in childhood do not exclusively depend on lifestyle choices, as these habits are heavily influenced by the living environment (Swinburn et al., 2019). Specifically, the family environment domains –family eating and physical activity behaviours, parenteral education and employment status, family economics– have an impact on children's habits. Among them, the family SES, that is usually measured considering three indicators –education, employment status and household income– is inherited by children as a strong determinant of their present and future health (Pilyoung et al., 2018; World Health Organization, 2016).

While diet quality follows a socioeconomic pattern in both children and adults, where healthier diets are associated with higher SES (Aranceta et al., 2003; Desbouys et al., 2020), limited evidence is available in relation to parenteral SES and physical activity in children, probably due to the lack of categorization of physical activity (leisure time, occupational, etcetera) (O'Donoghue et al., 2018). However, evidence related to leisure time shows that low SES children tend to have higher prevalence of sedentary behaviour than those with high SES (Inchley et al., 2016; Ministerio de Sanidad, 2018; Musić Milanović et al., 2021).

Globally, 81.0% of children aged 11-17 years old did not met the current recommendation of 60 minutes per day of moderate-to-vigorous physical activity for health, while around 13-15% of European children between 11 and 15 years old reported a daily intake of SSB and 33-44.0% a daily fruit consumption (Guthold et al., 2020; Inchley et al., 2016). In Spain, 14.0% of children aged 5-14 years had a sedentary behaviour in their leisure time in 2017, with low SES children spending more hours in screen-time behaviours on weekdays, and 45.2% and 57.3% referred a daily consumption of sweets and fruits, respectively (Ministerio de Sanidad, 2018).

Besides the family environment, other environmental components also shape food and physical activity behaviours: the social environment –social norms regarding body weight, physical activity, and diet–, the built environment –healthy food availability, transportation and walkability–, and the macroeconomic framework –fiscal and agricultural policies, trade agreements, food system– (Swinburn et al., 2011; Swinburn et al., 2019; World Health Organization, 2016). In particular, literature suggest that the built environment is influenced by the neighbourhood socioeconomic status (NSES), as living in neighbourhoods of low SES seem to be linked to a higher risk of unhealthy habits, independent of individual-level SES (Popkin et al., 2005; Wang et al., 2007).

Given the urgent necessity to address healthy habits in children due to their potential role in defining their present and future health, we decided to quantify the influence of socioeconomic factors at the individual and neighbourhood level in the Canary Islands, a Spanish autonomous region with 2,2 million inhabitants, located on the western coast of the African continent, and considered an outermost region of the European Union due to its insularity, remoteness, small size, and difficult topography. Specifically, for being a region with rates of obesity and overweight in children above the national average and with a worrying upward trend in the prevalence of obesity in pregnant women since 1993 (Alemán-Sánchez et al., 2022; Ministerio de Sanidad, 2018; Serra-Majem et al., 2022; Serra Majem et al., 2003). A few studies have used cross-sectional data or cohort studies to evaluate the effect of SES on diet and physical activity habits in the Canary Islands' children (Alemán-Sánchez et al., 2022; Instituto Canario de Estadística, n.d.). However, to our knowledge, this would be the first one evaluating SES and NSES simultaneously and, taking advantage of the universal coverage of the Spanish health system, using electronic health records data from the Canary Health Service well-child visits to their primary care health specialists.

Therefore, the aim of this study was to assess the effect of SES and NSES on two health determinants –diet and leisure time physical activity– among the Canary Islands children and adolescents.

5.2. Methods

5.2.1. Study design and participants

Cross-sectional study based on data for 2018 from all public primary healthcare centres in the Canary Islands. Participants were all individuals aged 6-18 years, residing in any of the 88 municipalities which form this archipelago and with at least one contact with primary health care during 2018. To avoid selection bias, we tentatively obtained anonymized data from 180,068 individuals, aged 6-18 years, registered in any primary health care centre during 2011-2018. As in the Canary Health Service well-child visits to their primary care doctor or nurse occur at 6, 9 and 12-14 years of age, we decided to restrict our dataset to individuals aged 6-14 years (n=176,027). Excluding individuals with missing values for SES (n=17), for the food (n=26,261) or physical activity surveys (n=59,685), or with a small sample size for the geographical unit definition (n=111); the final sample consisted of 89,953 individuals from 86 municipalities and 101 basic health zones (BHZ).

Public health service population coverage is shown in Table 21, where electronic health records cohort include 96.75% of the population from the census by 1st July 2018.

Table 21. Distribution of population by 1 July and study population in 2018.

		Census	Electronic health records	Population coverage
Age-group	**Sex**	n	n	%
5-9 years	Men	50773	48771	96.06
	Women	47977	46232	97.14
	Both	98749	95003	96.21
10-14 years	Men	57506	55862	96.36
	Women	54202	52735	97.29
	Both	111707	108597	97.22
All	Men	108279	104633	96.63
	Women	102179	98967	96.86
	Both	210456	203600	96.74

5.2.2. Variables and data sources

Individual data were obtained from the electronic health records of the Primary Healthcare Service in the Canary Islands, known as DRAGO-AP. These data include date of birth, sex, country of birth, municipality of residence, health area, BHZ, drug cost-sharing and data on the food and the physical activity surveys. These surveys are included in the "healthy child" universal program of the Canary Health Service, and they are performed by primary care health professionals.

Adherence to dietary recommendations: the food survey was used to assess the level of adherence to the dietary guideline issued by the Canary Health Service (Dirección General de Porgramas Asistenciales del Servicio Canario de Salud, 2012). This short food frequency questionnaire evaluated the intake of 7 food groups on a two-point yes/no scale, except for fruit group (fruit pieces consumption per day). Items were (1) daily intake of vegetables, (2) 0.5 litres of dairy products intake per day, (3) daily intake of meat, eggs, or fish, (4) frequent intake of sugar-sweetened beverages, (5) frequent intake of sweets, (6) 1-2 times a week intake of legumes and (7) number of fruit pieces per day.

Items on fruit and vegetable consumption were combined into a fruits and vegetables indicator as follows: daily intake of vegetables (1 point), at least two pieces of fruit per day (1 point). Analogously, items on sweets and SSB were used as an indicator of unhealthy eating. For consistency with the other indicators –higher values denote healthier habits–, these items where reverse coded: daily intake of SSB (0 points), daily intake of sweets (0 points). As a result of combining these two indicators –fruit and vegetables, SSB and sweets–, we obtained a diet scale range from 0 to 4 points, where 0 denotes an unhealthy diet and 4 refers to a healthy one.

Adherence to physical activity recommendations: the physical activity survey was used to assess the level of adherence to the guideline issued by the Canary Health Service (Dirección General de Porgramas Asistenciales del Servicio Canario de Salud, 2012). The questionnaire classifies physical activity into 5 groups –inactive/sedentary, partially active, active, very active and extremely active–, that we combined into 2 categories to assessed leisure time physical activity (Table 22). Thus, the physical activity indicator ranges from 0 to 1 point, where 1 refers to fulfilling the recommendation of 60 minutes per day of physical activity.

Table 22. Level of leisure time physical activity.

Physical activity level	Description
Inactive/partially active	- Daily use of public transport or private car in school journeys. - Absence or less than 1 hour a day of active leisure time.
Active	- Frequent active school journeys (walking, cycling). - More than 1 hour a day of active leisure time.

A healthy habits score, ranging from 0 to 4, was defined by the weighted sum of the previous indicators as follows: (1) $diet\ scale/2$ + (2) $physical\ activity\ x\ 2.$

The Spanish drug cost-sharing scheme of the National Health Service determines a level of coinsurance for each patient, based on their annual income and labour force status (Real Decreto-Ley 16/2012, de 20 de Abril, de Medidas Urgentes Para Garantizar La Sostenibilidad Del Sistema Nacional de Salud y Mejorar La Calidad y Seguridad de Sus Prestaciones., 2012). We used this drug cost-sharing classification as a proxy for SES of the family of participants: (1) integration minimum income, (2) annual income lower than €18,000, and (3) above €18,000.

Neither the residential addresses of the participants nor their postal code were available, so we could not use census tract level data to assess the neighbourhood socioeconomic conditions. As the BHZ was the smallest geographical unit in our dataset and these areas are defined according to various demographic and geographic criteria, but above all aiming to guarantee service proximity to users (Real Decreto 137/1984, de 11 de Enero, Sobre Estructuras Básicas de Salud, 1984), we decided to include as NSES variables the percentage of children within the BHZ whose families: (1) had an integration minimum income –low NSES–, (2) had an annual income lower than €18,000 –middle NSES–.

5.2.3. Statistical analysis

A stepwise multilevel lineal regression analysis by restricted maximum likelihood estimation was performed to examine the simultaneous influence that SES, NSES and the BHZ on the healthy habits score, differentiating between specific (% low NSES, % middle NSES) and general contextual observational effects (Hox, 1995; Merlo et al., 2016, 2019).

Model 1 is a multilevel lineal regression with BHZ as a random effects variable and keeping individual covariates as fixed effects. Finally, model 2 incorporated the specific contextual observational effects. The final model can be written as:

$$y_{ij} = \beta_0 + \sum_{k=1}^{4} \beta_k x_{kij} + \beta_5 z_{5j} + \beta_6 z_{6j} + u_j + e_{ij},$$

where y_{ij} is the healthy habits score estimate for an individual i living in an area j; x_{kij} are the individual explanatory variables in an area j (age group, sex, country of birth and SES); β_k, the fixed-effect regression coefficients; z_{5j} *and* z_{6j}, are, respectively, the neighbourhood covariates of interest (NSES: % low NSES, % middle NSES); u_j, the area-level random error; e_{ij}, the individual-level random residual error.

We also calculated (1) the variance partition coefficient (VPC) to measure the proportion of total variance attributable to differences between BHZ, and (2) the proportional change in variance (PCV) to know if the general contextual variables were substantially mediated by the specific contextual variables.

Statistical analyses were performed using the statistical software Stata/SE version 14 (Stata Corp., College Station, TX, USA).

5.3. Results

Table 23 shows a description of the study population and its distribution according to their diet and physical activity level. No differences were found by sex, except for frequent SSB consumption and fulfilling the recommendation of 60 minutes per day of physical activity. Specifically, a higher proportion of boys had a frequent consumption of SSB ($p<0.01$) and an active physical activity level ($p<0.01$).

Adherence to healthy habits decreased with age, so that older children had worst diet and physical activity habits than younger ones ($p<0.01$). Although just 5.2% of the sample were foreign born children, this group had a higher proportion of frequent SSB and sweets consumption ($p<0.01$). However, no differences were found in daily intake of fruits and vegetables, or in the active physical activity level.

Even though adherence to healthy habits decreased significantly in children with lowest SES ($p<0.01$), at the neighbourhood level this gradient is not clear. While children from BHZ with lower percentage of families with annual incomes below the €18,000 threshold (first tertile of middle NSES) had a higher adherence to healthy habits ($p<0.01$), having a higher proportion of families with an integration minimum income (third tertile of low NSES) did not necessarily mean lower levels of adherence to the dietary recommendations. Though, third tertile of low NSES showed a lower proportion of fulfilling the recommendation of physical activity.

In the study population, the mean healthy habits score was 2.8 points (SD 1.1), with a 23.5% of the children fully complying with the dietary and physical activity recommendations (4 points) and a 9.7% of the children with an unhealthy diet and being physically inactive (0-1 points). Among the physically active children (71.8%), the mean score was 3.4 (SD 0.5), meaning that 1.4 points out of 2 were attributable to the diet (87.8% daily intake of vegetables and 51.2% daily intake of 2 or more pieces of fruit). However, being physical active was more frequent in children with an occasional intake of SBB and sweets (61.4%) than in those with a daily intake of fruits and vegetables (48.7%).

Table 24 shows individual and contextual variables associated to the healthy habits score across the two multilevel regression models. Girls, foreign-born and older children showed a lower adherence to the diet and physical activity recommendations ($p<0.01$). The healthy habits score followed a socioeconomic gradient in the individual level (SES), as children living in more affluent families were more likely to follow a healthy diet and being physically active ($p<0.01$).

Table 23. Study population.

		Daily intake of vegetables		Daily intake of ≥ 2 pieces of fruit		Frequent intake of SSB		Frequent intake of sweets		Active physical activity level	
	N	n	%	n	%	n	%	n	%	n	%
Sex											
- Boys	45677	39369	86.2	22012	48.2	17361	38.0	9170	20.1	34769	76.1
- Girls	44276	38214	86.3	21491	48.5	15759	35.6	8911	20.1	29805	67.3
Age (years)											
- 6-8 years	27390	25157	91.9	14906	54.4	8979	32.8	4457	16.3	20488	74.8
- 9-11 years	25159	21691	86.2	12292	48.9	9108	36.2	4842	19.3	18275	72.6
- 12-14 years	37404	30735	82.2	16305	43.6	15033	40.2	8782	23.5	25811	69.0
Country of birth											
- Spain	85278	73594	86.3	41245	48.4	31198	36.6	16859	19.8	61271	71.9
- Other	4675	3989	85.3	2258	48.3	1922	41.1	1222	26.1	3303	70.7
SES											
- Low	4957	4217	85.1	2284	46.1	2170	43.8	1188	24.0	3191	64.4
- Medium	63278	54177	85.6	29610	46.8	24805	39.2	13621	21.5	44272	70.0
- High	21718	19189	88.4	11609	53.5	6145	28.3	3272	15.1	17111	78.8
NSES low											
- Tertile 1	29179	24898	85.3	14330	49.1	10687	36.6	6179	21.2	21203	72.7
- Tertile 2	30440	26410	86.8	14349	47.1	11159	36.7	5427	17.8	22362	73.5
- Tertile 3	30334	26275	86.6	14824	48.9	11274	37.2	6475	21.4	21009	69.3
NSES medium											
- Tertile 1	30403	26497	87.1	15715	51.7	10485	34.5	6007	19.8	22629	74.4
- Tertile 2	31236	27114	86.8	15162	48.5	11350	36.3	6075	19.5	22571	72.3
- Tertile 3	28314	23972	84.7	12626	44.6	11285	39.9	5999	21.2	19374	68.4

Table 24. Individual and contextual factors associated with the healthy habits score. Multilevel regression analysis.

	Model 1		Model 2	
	Coef.	95% CI	Coef.	95% CI
Sex				
- Boys	Ref.	Ref.	Ref.	Ref.
- Girls	-0.158	-0.172; -0.144	-0.158	-0.172; -0.144
Age (years)				
- 6-8 years	Ref.	Ref.	Ref.	Ref.
- 9-11 years	-0.131	-0.150; -0.113	-0.131	-0.150; -0.113
- 12-14 years	-0.292	-0.309; -0.275	-0.292	-0.309; -0.275
Country of birth				
- Other	Ref.	Ref.	Ref.	Ref.
- Spain	0.047	0.015; 0.080	0.047	0.015; 0.080
SES				
- Low	Ref.	Ref.	Ref.	Ref.
- Medium	0.149	0.118; 0.180	0.149	0.117; 0.180
- High	0.436	0.403; 0.470	0.436	0.403; 0.469
NSES low			-0.005	-0.024; 0.015
NSES medium			-0.007	-0.013; -0.001
VPC (%)	1.836	1.382; 2.435	1.772	1.329; 2.360
PCV (%)			3.519	3.874; 3.163

Regarding the specific contextual effects, the addition of NSES variables did not improve much the model fit to the data, with a reduction of just 0.002 (95% CI: 0.002; 0.003) in the BHZ estimated variance. While having a higher percentage of population with an integration minimum income within the BHZ (NSES low) was not associated with the healthy habits score, the adherence to the dietary and physical activity recommendations seemed to be significantly lower in the BHZ with a higher percentage of annual incomes below the €18,000 threshold (p=0.03).

Differences in the healthy habits score between BHZ seemed to be of minor relevance, as these variations represented only 1.8% of the total individual variance in both models. Even though middle NSES was significantly associated with the healthy habits score, the small PCV found (3.5%) suggest that the general contextual effects were not substantially mediated by the NSES.

5.4. Discussion

This study aimed to assess the effect of socioeconomic status at the individual and neighbourhood levels on a healthy habits score –based on diet and leisure time physical activity–, differentiating between specific and general contextual effects.

Our findings have shown a strong association between SES and the healthy habits score, though the geographical component seems to be small since accounting for the BHZ gave a VPC of just 1.8%. This does not mean that there are no geographical inequalities in the adherence to the dietary and physical activity recommendations, but that there might be other types of contextual factors different than the BHZ conditioning the healthy habits score. As children spent most of their time at school, using the surrounding school areas as geographical unit might have better capture the relevant NSES context that influences children's habits.

Despite NSES does not appear be a relevant factor in the contextual effect of the BHZ (PCV=3.5%), we found a negative association between middle NSES and the healthy habits score so that the BHZ with lower incomes showed a lower adherence to the dietary and physical activity recommendations. A difference of 0.18 in the healthy habits score was observed between the BHZ with the highest percentage of families with annual incomes below the €18,000 threshold and the lowest one, which represents around 8.5% of the mean healthy habits score. On the contrary, we found no association with being in a BHZ with a higher percentage of population with an integration minimum income (NSES low). This could be explained due to the high degree heterogeneity of this group –people with non-contributory retirement pension, with severe disabilities, long-term unemployed, etc.– (Real Decreto-Ley 16/2012, de 20 de Abril, de Medidas Urgentes

Para Garantizar La Sostenibilidad Del Sistema Nacional de Salud y Mejorar La Calidad y Seguridad de Sus Prestaciones., 2012), where people are not just classified by income but by their current administrative situation. In fact, the low NSES group might has similar income levels than the middle NSES, as the first ones are entitled to income and benefits in kind.

Overall, previous studies have also found an association between healthier diet patterns and higher SES in children (Aranceta et al., 2003; Desbouys et al., 2020), however only a few studies showed a positive significant association with physical activity (Ferreira et al., 2007; O'Donoghue et al., 2018). This might be due to the different socioeconomic indicators used –education, occupation, income or composite scores of SES–, as they covered different areas of the social construct (Geyer et al., 2006). Studies that use composite scores of SES do not usually find a significant relationship with physical activity, but when single components of SES are used, such as mother's education level or family income, a positive association was observed in adolescents (aged 13-18 years) (Ferreira et al., 2007).

In Spain, single SES indicators seem to be associated to movement behaviours in children and adolescents (Instituto Canario de Estadística, n.d.; Ministerio de Sanidad, 2018; Román-Viñas et al., 2006), though depending on the movement behaviour indicator used the direction of the association with SES varies. While active play and transport to and from school is more frequent in low SES children, practicing sports can be more easily engaged by children from high SES families as it usually implies additional costs (Musić Milanović et al., 2021; O'Donoghue et al., 2018).

Regarding NSES and its association with dietary and physical activity habits in children, findings are inconsistent. While most studies have shown a non-significant association (Kim et al., 2019), a study on US children aged 10-12 years found that neighbourhood affluence –percentages of households with high income, executive or professional jobs, and with a college education– was inversely associated with unhealthy eating and sedentary behaviours (Carroll-Scott et al., 2013). Another study on Scottish pupils aged 15-16 years also found an inverse relationship between an area-level multiple deprivation index and having a poorer diet (Levin, 2014). A population-based cohort study in Finland, which followed up participants over 30 years, showed that individuals living in low NSES areas had a lower consumption of vegetable and fruits from the age of 6 years, and also a lower physical activity from 12 years old. However, the cumulative exposure to a low NSES yielded the greatest differences from childhood to adulthood, increasing the odds of developing cardiometabolic risk factors and diabetes (Kivimäki et al., 2018). Thus, it is highly likely that the widespread use of single-point measures of NSES may worse capture the effect of contextual factors that take time to reverse (Do, 2009).

Understanding that interactions with the neighbourhood environment vary with age is crucial to foster meaningful changes in children's habits. Whereas younger children are more influenced by their caregivers, older ones are more constrained by their peers and directly engaged with the living environment. The effect of these interactions also differs among NSES level, being youth from high NSES less dependent on the environment that surrounds them (De Meester et al., 2012; Fox & Timmer, 2020), perhaps due to the fact that more affluent areas have a lower exposure to obesogenic environments than their peers from low NSES (Pilyoung et al., 2018; Popkin et al., 2005; Swinburn et al., 2019).

Therefore, interventions to promote healthy habits in children would necessarily need to consider their changing conditions among time and their interactions across the different domains of the living environment to succeed.

There are several strengths and limitations in this study. The universal health coverage allowed us to study all the individuals aged 6-14 years from a Spanish autonomous region with a population of more than 2 million people, as a means of assessing representativeness of the target population. However, the high proportion of children with missing values, which made multiple-imputed analysis not desirable, might have biased our results but made them representative of paediatric patients who had well-child visits in the study year. In addition, the cross-sectional design cannot establish causal associations, but still provides valuable descriptive information. Because of the electronic health record surveys design, we used dichotomised variables instead of quantitative intake to assess adherence to the dietary recommendations, and classified children according to their overall leisure time physical activity that may not have captured all aspects of the movement behaviours –physical activity, sedentary lifestyle, and sleep time–. Although the use of a composite dependent variable to assess healthy habits in children did not allow us to make accurate comparisons with other studies, from a public health perspective, our results might provide valuable information for the design of health promotion strategies in childhood. Finally, the potential confounding effects of unmeasured variables may be an important source of bias in our study.

5.5. Conclusions

Our research suggests that healthy habits in children followed a socioeconomic gradient at the individual and the neighbourhood level, so that children from more affluent families and areas show higher levels of adherence to the dietary and physical activity recommendations.

As the geographical component of the inequalities found were low, further research should focus on other contextual factors conditioning the healthy habits score.

Targeting socioeconomic inequalities will be crucial to promote healthy habits in children, with a positive impact in health throughout the life-course.

6. CONCLUSIONS & FURTHER RESEARCH

- The importance of the environmental context on diet is recognized, as tourist pressure influences the adherence to the Mediterranean diet pattern in the Canary Islands' population.

  - The SES of tourists seems to be determinant in the direction of the effect, driving food habits of the local inhabitants.

  - Further investigation on other highly touristic destination is needed for a deeper understanding of the association between tourist pressure and local population diets, that could contribute to a shift on tourism and public health nutrition policies.

- The potential withdrawal of the sugar and BCS subsidies from the specific supply arrangements of the Canary Islands was predicted to avoid 10363 cases of obesity over the study period, due to the reduction of the obesity prevalence by -0.7 percentage points in 2007-2016.

  - BCS subsidies ranged from 1.0% to 39.0% of the retail price in the study period and, and despite the decline trend in these subsidies, sugar subsidies have remained more than 20.0% during the whole period.

  - A potential average reduction of -74.7 and -125.4 kcal/capita in daily energy intake was attributable to the withdrawal of the sugar and BCS subsidies, respectively.

  - Elderly and lower SES groups would be the main beneficiaries of the policy, although the intervention might be beneficial to the food system as well.

  - Within the limitations and assumptions made in this study 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.

- Healthy habits in children followed a socioeconomic gradient at the individual and the neighbourhood level, so that children from more affluent families and areas show higher levels of adherence to the dietary and physical activity recommendations.

  - As the geographical component of the inequalities found were low, further research should focus on other contextual factors conditioning the healthy habits score, as these will be crucial to promote healthy habits in children, with a positive impact in health throughout the life-course.

- This PhD dissertation has opened up many fields of research, but there are still many to be explored, being this thesis a first step of what is to come in a near future.

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8. APPENDIX

8.1. Annex I

8.1.1. Population projection method.

Firstly, we obtained deciles of the baseline body mass index (BMI) distribution by sex, age and SES in the 1998 and 2015 populations. For each decile of the baseline BMI distribution in the 1998 population (BMI_{1998}), sex, age, and SES, we calculated the mean of changes in the BMI distribution attributable to the intervention –without subsidies scenario in 1998–. Afterwards, the mean of changes calculated for each decile of the BMI_{1998}, sex, age, and SES in the 1998 population were applied to each individual of the 2015 population with the same decile of BMI_{2015}, sex, age and SES group. The table below is shown as an example to illustrate the calculations made:

	1998 population	
	Males, 55-64 years old, low SES and 7th decile of baseline BMI distribution (29.02-29.23)	Females, 55-64 years old, low SES and 7th decile of baseline BMI distribution (29.09-30.78)
Mean of changes in BMI:	-0.1128	-0.1022
	2015 population	
	Participant A, a 58-year-old man, with a low SES and a BMI in the 7th decile of the baseline BMI distribution (28.01-29.00)	Participant B, a 62-year-old woman, with low SES and a BMI in the 7th decile of the baseline BMI distribution (26.22-27.34)
Change in the BMI attributable to the intervention:	Taken from the mean of changes in the 1998 population = -0.1128	Taken from the mean of changes in the 1998 population = -0.1022
Baseline BMI (with subsidies):	28.18	27.02
Counterfactual BMI (without subsidies):	28.07	26.92

A male subject in 2015, with 55-64 years old, low SES and a baseline BMI in the 7th decile of the group's BMI distribution (BMI 28.01-29.00) will show a variation in his BMI equal to the mean of changes in BMI of the group of males, with 55-64 years old, low SES and a baseline BMI in the seventh decile of the 1998 population (29.02-29.23).

8.2. Annex 2.

8.2.1. Publications

- ***"Effect of tourism pressure on the Mediterranean diet pattern".***

  Authors: Silvia Rodríguez-Mireles, Beatriz G. López-Valcárcel, Lluís Serra-Majem, Aránzazu Hernández-Yumar, Patricia Barber-Pérez, Jaime Pinilla-Domínguez, Santiago Rodríguez-Feijoo & Alejandro Rodríguez-Caro.

  Journal reference: Nutrients 2018, 10(10), 1338.

  DOI: 10.3390/nu10101338

  JIF JCR, 2018: 4.171

  JIF quartile and rank: Q1, 16/87 in Nutrition & Dietetics (SCIE).

- ***"When industrial policies conflict with population health: potential impact of removing food subsidies on obesity rates".***

  Authors: Silvia Rodríguez-Mireles, Beatriz G. López-Valcárcel & Lluís Serra-Majem.

  Journal reference: Value in Health 2020, 24(3), 336-343.

  DOI: 10.1016/j.jval.2020.12.005

  JIF JCR, 2020: 5.728

JIF quartile and rank: Q1, 23/376 in Economics (SSCI); Q1, 4/88 in Health Care Sciences & Services (SSCI); Q1, 9/107 in Health Care Sciences & Services (SCIE).

- ***"Socioeconomic disparities in diet and physical activity in children: evidence from well-child visit electronic health records".***

  Authors: Silvia Rodríguez-Mireles, Beatriz G. López-Valcárcel, Patricia Galdós-Arias, Enrique Pérez-Díaz & Lluís Serra-Majem.

  Journal reference: Journal of Epidemiology & Community Health, 2023 (under review).

  JIF JCR, 2021: 6.286

  JIF quartile and rank: Q1, 21/182 in Public, Environmental & Occupational Health (SSCI); Q1, 41/210 in Public, Environmental & Occupational Health (SCIE).