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Food policies and population health

Soda taxes, FOP labelling, and population health: a global longitudinal analysis

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Abstract

Obesity is a global problem with serious health and economic consequences, including diabetes and other NCD. Governments should employ obesity-fighting policies with proven effectiveness, like soda taxes and FOP labelling. Statistical evidence supports the association between beverage taxes and health outcomes, while the significance of FOP remains uncertain. Instead of general funds, governments must allocate beverage tax revenues to obesity prevention initiatives. Due to reformulations, global beverage tax revenues have been less than anticipated, with parts still unaccounted for. Education is also crucial in the fight against obesity, and policymakers must establish incentives for businesses to make healthier dietary choices.

Keywords

SSB Tax, Soft Drinks, Obesity, Diabetes, Sugar-Sweetened Beverages, FOPs, Food Labels, Food Label Policies, Soda Tax Revenues, SDIL, Earmarked Revenues

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List of Abbreviations

BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
FDA	Food and Drug Administration
FOP	Front-of-pack
GBD	Global Burden of Disease
GDP	Gross Domestic Product
IHME	Institute for Health Metrics and Evaluation
LDL	Low-density lipoprotein
NCD	Non-communicable diseases
PE	Physical education
SDIL	Soft Drinks Industry Levy (tiered soft drink tax in the UK)
SSB	Sugar-Sweetened Beverages
WHO	World Health Organization

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General introduction

In recent years, the global rise in obesity has become a critical public health concern, with serious consequences for both individuals and society at large. Obesity is linked to a variety of chronic diseases, including type 2 diabetes, cardiovascular diseases, and certain types of cancer (WHO 2021a). Exacerbated by the increased availability and marketing of energy-dense, nutrient-poor foods, the challenge of addressing obesity has given rise to a multitude of policy interventions, such as taxation and food labelling requirements. The primary aim of this thesis is to investigate the relationship between different food policies and obesity, focusing on identifying the policies most effective at reducing rates of obesity in various populations.

We start with a general overview of food policies to combat obesity. Based on desk research, we identify the various policies that governments across the world have implemented, map where key policies are in place —namely, soda taxes and Front-of-Package (FOP) labelling requirements—, and summarize their main impacts as documented in the literature.

Using statistical analysis, Part A of this thesis investigates the effects of soda taxes and FOP labelling requirements on population health. We combined information on if and when each country introduced a soda tax of FOP labelling requirements with data on the prevalence of overweight and obesity, type 2 diabetes, and other population health indicators, to create a panel of countries observed over 10 years. We apply panel data regression with country-fixed effects and control for several time-varying variables like GDP and health expenditure.

Part B explores the uses of government revenues from soda taxes, focusing on the UK. We compare and analyze the intended and actual utilization of soda tax revenues, by investigating government reports and academic papers. The aim is to determine whether soda tax revenue spending was in accordance with government commitments and WHO recommendations. Despite the UK's focus, other countries with a soda tax are also considered. A summary of results and their implications for policy and future research conclude this thesis.

Part 0: Policy options to combat obesity

(Group part)

1. Background

According to WHO, adults with a body mass index (BMI) of 25 or above are considered overweight, and those with a BMI of 30 or higher are classified as obese. Obesity and overweight can be caused by an imbalance between the amounts of energy ingested and energy expended. Obesity can be genetically predisposed, while social and cultural factors also play a significant role in its development (Locke et al. 2015). Additionally, environments that discourage or make healthy dietary and physical activity choices more difficult are obesogenic (e.g., neighborhoods that lack green spaces for outdoor activities or where a majority of dining options are fast food restaurants; Mackenbach et al. 2014). Obesogenic environments are predominantly low-income areas, which may contribute to inequalities in nutrition-related health outcomes (Atanasova et al. 2022).

There has been a global shift in average energy intake/energy expended, with individuals consuming more energy-dense meals and participating in substantially less physical exercise (Popkin, Adair, and Ng 2012). Research suggests that wealthier nations have a higher prevalence of obesity and that a 1% increase in gross domestic product (GDP) correlates with a similar increase in the prevalence of obesity (Talukdar et al. 2020). This is partly related to the abundance of (processed) food, rich in sugar, fat, and salt, and an increase in the proportion of sedentary jobs (Popkin, Adair, and Ng 2012).

Since 1975, worldwide obesity has nearly tripled, and in 2016, over 1.9 billion adults were overweight, with over 650 million being obese. Additionally, in 2020, nearly 400 million children and adolescents aged <19 were also affected by overweight or obesity, emphasizing the need for effective prevention strategies (WHO 2021b). Obesity is a well-established risk factor for many noncommunicable diseases (NCD), including cardiovascular disorders, cancers, and especially, type 2 diabetes, as it correlates with other risk factors for NCD like high systolic blood pressure and high low-density lipoprotein (LDL) cholesterol (Institute for Health Metrics and Evaluation 2019). According to the International Diabetes Federation (2019), around 463 million persons suffered from diabetes in 2019. By 2045, this number is anticipated to increase to 700 million. Such health developments illustrate the need for political intervention, in the form of legislation and policies, to combat obesity and mitigate its adverse health impacts.

2. Methods

In this study, we identified the food-related policies implemented across the world through desk research. We searched the UNC-Chapel Hill Global Food Research Program database (https://www.globalfoodresearchprogram.org) and the NOURISH and MOVING policy databases (https://policydatabase.wcrf.org) in order to obtain information on 1) policy options and 2) where and when policies were implemented. We completed and corroborated that information using additional sources and conducted a literature search to identify the effects of the policies.

3. Results

3.1. Policies and measures against obesity

Some nations have implemented mandatory and voluntary food policies to encourage healthier diets through four main mechanisms: providing an environment favorable to healthy preferences, reducing barriers to living a healthy lifestyle, encouraging individuals to review their unhealthy shopping choices, and promoting food system reactions (Hawkes et al. 2015).

Indeed, food policies can have a direct or indirect effect on the supply and prices of goods, the information consumers receive, and consumer behavior.

3.2. Soda taxes

As a significant source of added sugar in the diets of many individuals, and a significant contributor to obesity and type 2 diabetes, sugar-sweetened beverages (SSB), such as soda, have been a subject of particular concern. The WHO (2017b) recommends that countries tax soda to help reduce its consumption and prevent obesity, by increasing the prices of the drinks and encouraging producers to reformulate. Taxation is also an effective way to raise revenues to pay, for example, for rising healthcare costs associated with the growing burden of NCD (further discussed in Part B).

According to WHO (2022), more than 85 countries have implemented some kind of SSB tax. SSB taxes can take different forms but mostly consist of an excise tax on the production or sale of SSB. SSB taxes are generally volume-based, meaning that the amount of the tax varies according to can/ bottle size. Most countries still impose a flat or single-tier tax on sugary beverages (e.g., one peso per liter in Mexico), whereas more recently, countries began to tax soda depending on sugar content, by imposing a greater tax on beverages with higher sugar content (i.e., multi-tier tax, e.g., 18 pence per liter for drinks with 5-8 grams of sugar per 100mL, 24 pence per liter for drinks with more than 8 grams of sugar per 100mL in the UK; Chriqui et al. 2013). The maps in Figure 1 show the global trend in the implementation of soda taxes between 2010 and 2019. They show that more countries have introduced either single-tier SSB taxes (1) or multi-tier taxes (2) over that period.

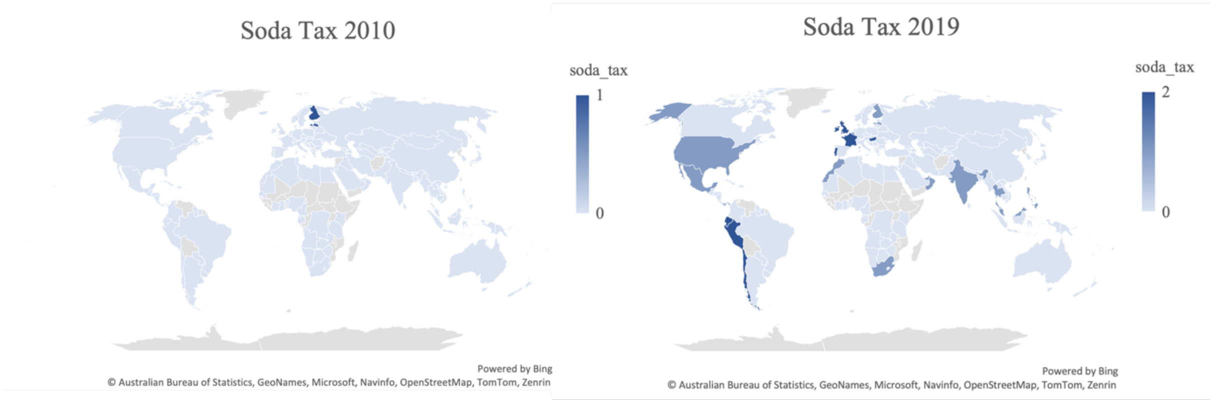


Figure 1: Soda taxes across the world, 2010 vs. 2019

Note: In the US, there isn't a national soda tax. Rather, there are several cities that have introduced soda taxes, namely Boulder (Colorado), Philadelphia (Pennsylvania), Seattle (Washington), and four California cities: Albany, Berkeley, Oakland, and San Francisco (UNC-Chapel Hill 2023).

In 2014, Mexico was one of the first nations to introduce a sugar tax, which applied to sugary foods as well as beverages with added sugars and caloric content exceeding 5kcal/100mL. The levy was set at one peso per liter and was projected to raise the price of sugary drinks by 12% (Colchero et al. 2016). A study discovered a 5.5% decrease in sugary drink consumption among adults one year after the tariff was enacted (Barrientos-Gutierrez et al. 2018). Research conducted two years after the adoption of the tax revealed a 7.6% decrease in sugary drink purchases (Colchero et al. 2017). Considered a success, the Mexican sugar tax has served as a model for other nations implementing similar measures.

Obesity rates are particularly high in Latin America, with 24 countries recording a proportion of obese people equal to or greater than 20% of the population. This has led to these nations being early adopters of sugar taxes as a public health intervention (Pan American Health Organization and Food and Agriculture Organization of the United Nations 2017; Duran et al. 2021). To tackle increasing rates of obesity, Chile increased its levy on beverages with added sugars and caloric content above 6.25kcal/100mL from 13% to 18% in 2014 (Caro et al. 2018). Through the tax increase, studies revealed a 21.6% decrease in sugary beverage purchases, with the highest decrease seen in low-income households (Nakamura et al. 2018). A study in Argentina, where there isn't yet a soda tax, used household microdata to analyze the price elasticity of SSB and estimate the impacts of implementing a hypothetical soda tax. The results were values ranging between -1.10 and -1.15, meaning that if prices would increase by 10%, the number of sugary beverages consumed would drop by between 11.0 and 11.5% (Maceira et al. 2023).

In the US, soda taxes have been implemented at the city level, rather than the state or national level. For example, according to a study conducted in Berkeley, California, the taxation of SSB, by 1 cent per ounce, led to a 21% reduction in sugary drink consumption (Falbe et al. 2016).

In 2018, the UK imposed a soda tax on beverages with added sugars. The tax was set at 18 pence per liter for beverages with a sugar level between 5 and 8 grams per 100mL, and 24 pence per liter for beverages with a sugar content of more than 8g/100mL (Forde et al. 2022). Research conducted one year after the adoption of the levy revealed a 28.8% decrease in the sugar content of beverages subject to the SDIL (Public Health England 2019). Many popular soft drinks have been reformulated in response to the UK's soda tax, which has been deemed a success. Reformulation incentives arise because of the multi-tier design, as manufacturers can pay a lower tax by decreasing sugar content below the 8 grams per 100mL threshold (Allais et al. 2023). A study also estimated that the UK soda tax could result in 144,000 fewer adults with obesity and 19,000 fewer cases of type 2 diabetes (Briggs et al. 2017). According to the World Cancer Research Fund International, the levy led to a reduction of over 5,000 cases of obesity among girls aged 10 and 11 years old in the sixth year (O'Mara and Vlad 2023). A (multi-tier) soda tax can incentivize multiple responses from manufacturers. For example, following the Irish soda tax, implemented in 2018, Coca-Cola Ireland reformulated drinks and started to offer more drinks with no or less sugar. They have allegedly passed on the sugar tax completely to retailers. Additionally, the sizes have changed, e.g., they have adjusted the size of the original Coca-Cola, whose sugar content was not adjusted in order not to change the original recipe appreciated by many customers (now only 1.5L instead of 1.75L bottles are available for purchase). In contrast, the sizes of Coke Zero Sugar or Diet Coke were increased from 1.75L to 2L (Coca-Cola Company n.d.).

Overall, although not every study has found a significant impact of soda taxes on consumption, the majority has, and according to Andreyeva (2022), a meta-analysis of 33 articles, covering 16 SSB taxes, estimates a 9%-20% reduction in SSB sales (95% confidence interval). Therefore, soda taxation could result in an improvement in public health (Andreyeva et al. 2022). A 20% levy on sugary drinks might lower obesity rates by 3.5%, resulting in major health benefits (Teng et al. 2019). Introducing soda taxes can also create revenue for public services and goods such as healthcare, education, and infrastructure (Part B).

However, the effectiveness of soda taxes may vary, depending on variables such as the targeted population and tax rate. Despite evidence of their efficacy, many nations have not yet implemented such levies (Backholer et al. 2016). In fact, new taxes are highly unpopular with voters. Besides, the introduction of soda taxes is often criticized for being regressive because soda taxes disproportionately affect households with lower incomes (Edmondson et al. 2022), as soda taxes are mostly passed on to the consumers (Seiler, Tuchman, and Yao 2020). In addition, a soda tax focuses solely on sugar as an ingredient. It may affect the intake of sugary soft drinks, but it does not eliminate the underlying cause of obesity. Obesity has to do with energy balance (see Background), which must not be neglected, and if calories are consumed from other unhealthy foods and drinks, in alternative to sugary beverages, then a tax on soft drinks tackles only a portion of a much larger problem (Griffith, O'Connell, and Dubois 2018). Lastly, the fact that the soda industry has been known to oppose soda taxes using lobbying and advertising to manipulate public opinion is a further reason why soda taxes may not be adopted.

In 2018, the soda industry spent millions to defeat soda tax plans in California (Silver et al. 2017). Despite limitations, soda taxes seem to be an effective policy against sugar overconsumption and can generate revenues for complementary public health measures (Part B).

3.3. Front-of-package labelling requirements

Another very common policy are front-of-package (FOP) labelling requirements. FOP labelling involves warning or instructional labels to educate consumers about healthier options or to draw attention to potentially harmful ingredients (Roberto et al. 2021). FOP labelling has been implemented primarily to assist consumers to make informed and healthier choices (Champagne et al. 2020) but can also encourage the industry to reformulate products in the direction of healthier alternatives. Since 1989, FOP labels have been designed to influence nutrition and to prevent obesity and diabetes (Muzzioli et al. 2022). Organizations such as the International Heart Federation advocate for the implementation of mandatory FOP labels. Presently, just the declaration of ingredients, nutritional information, and allergens on food labels are mandatory in Europe (Engelhardt et al. 2023). Yet, some countries have already introduced additional voluntary FOP labelling policies, which are more visible than the existing back-of-package information, to provide consumers with more information. The maps in Figure 2 show which countries had voluntary (1) or mandatory (2) FOP labelling requirements in 2010 and 2019. A rise in popularity for such labels can be seen globally.

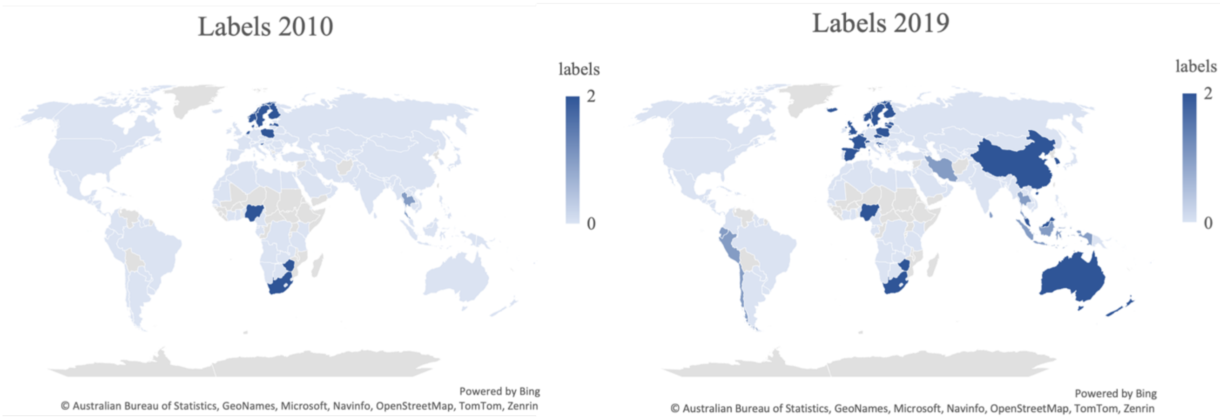
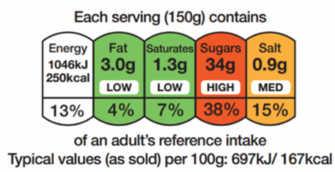
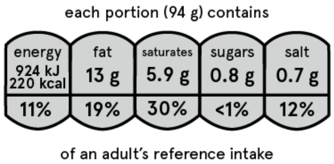


Figure 2: FOP labelling requirements across the world, 2010 vs. 2019

There is substantial variety in FOP nutrition labelling schemes across the globe. Labels may vary e.g., in size, shape, or color (Kanter, Vanderlee, and Vandevijvere 2018). As recommended by the Institute of Medicine of the National Academies, the most prevalent schemes include values for sodium, fats (saturated, trans), and total sugars (McGuire 2012). Table 1 provides an overview of voluntary FOP labelling initiatives implemented during 2010-2019.

Table 1: Overview of FOP labels

Label	Name and Description	Implemented in
NUTRI-SCORE A B C D E	**Nutri-Score:** Classifies food products into five categories based on nutritional quality, from A (dark green, high nutritional quality) to E (red, poor nutritional quality).	France (2017) and adopted by several other European countries (European Food Information Council 2022).
	**UK traffic light scheme:** Combines the percentage reference intake label with a color-coding system to indicate the nutritional value of food products.	UK (2013) (BBC 2016; (Food Standards Agency 2020).
HEALTHY CHOICE ® BASED ON INTERNATIONAL DIETARY GUIDELINES	**The Choices logo:** An endorsement program that allows food products with healthier nutritional profiles within a product category to display this seal.	Poland, Czech Republic (previously in the Netherlands, withdrawn in 2017; Storcksdieck et al. 2020).

	**Reference Intake Label:** Indicates the amount of energy and nutrients (fat, saturates, sugars, and salt) in a portion of food and what percentage of the daily reference intake (2000 kcal/day) that portion represents.	Developed in 2006 and updated in 2011, introduced in Europe, with color-coded versions in Portugal and Spain (FOODDRINKEUROPE 2014).
	The Keyhole Symbol: Represents healthy options within 32 food groups, meeting specific standards for fat, sugar, salt, wholegrain, and fruits and vegetables.	Sweden, Denmark, and Norway in 2009 (World Cancer Research Fund International 2016).

Depending on the design, FOP labels can be more or less effective. A study found that traffic light styles are easier to compare and interpret and are thus more effective in promoting healthier food choices, compared to the nutrition table format or the recommended daily amounts (Siegrist, Leins-Hess, and Keller 2015). Traffic light systems can help children and people especially focused on reducing intake of one main ingredient, like sugar, fat, or salt. Other easily visible symbols, such as the Choices logo and the Keyhole Symbol, help consumers find healthier food options when shopping. Regarding the reference intake label, which contains solely numbers, buyers with low levels of education may have difficulties understanding it. In addition, the references are based on the healthy weight and average activity level of adults, making it less useful for consumers such as children, pregnant women, and the elderly (Tarabella and Voinea 2013). Overall, the use and comprehension of FOP labels are also influenced by differences in interest in healthy eating, nutrition knowledge, and socioeconomic status (Grunert et al. 2010).

Limitations of FOP labels are first, that they mainly emphasize poor nutrients, and it can be difficult to evaluate foods of the same category that may also include rich nutrients. Another limitation is that FOP labels are blind to quantity or frequency of consumption, and some consumers may indulge in green-labeled products in a manner that eventually has a detrimental impact on their nutritional intake (Tarabella and Voinea 2013).

Evidence suggests that the adoption of FOP labels has been mildly beneficial. After the implementation of FOP labelling in Chile in 2016 (labelling system including warnings for high-sugar, high-sodium, and high-saturated fat items), the purchase of sugary beverages decreased by 23.7% (Taillie et al. 2020). However, this only amounts to daily savings of 23mL per individual, or 9 calories (Geldart 2023). Another study revealed that after the introduction of the Choices label in the Netherlands, sales of products with the label increased, which could indicate that customers are making better food choices (Smed, Edenbrandt, and Jansen 2019).

In conclusion, while FOP labels can be beneficial in promoting healthy eating habits and boosting transparency in the food sector, they can also be costly to implement and may not necessarily address all health problems successfully. The existing FOP labels show advantages but there is still room for improvement. Nevertheless, in 2019, one million Europeans signed a petition to make the Nutri-Score mandatory across Europe (Connexion journalist 2019), and the International Agency for Research on Cancer, which is part of the WHO, urged the EU Commission to establish the Nutri-Score on a mandatory basis throughout Europe. However, national legal obligations preclude labelling from becoming required under European law (WHO 2021b). In 2020, the European Commission endorsed the Farm to Fork Strategy, which also involves developing a system to provide consumers with more and clearer information so they can make better and healthier decisions via standardization of the required FOP nutrition labels (European Commission n.d.).

3.4. Additional measures to combat obesity

Besides soda taxes and FOP labelling policies, governments have implemented a range of other measures to combat obesity. *Reformulation agreements* involve working with food manufacturers to reduce the sugar, fat, and salt content of their products. For example, the UK government has successfully launched a sugar reduction program that involves reformulation agreements with the food industry. This approach has resulted in significant sugar content reductions in numerous goods. Lithuania is a further illustration of this type of action, where the government agreed to put the implementation of a sugar tax on hold if food makers significantly cut the salt and sugar content of their products (News Desk 2018). The feasibility and social acceptability of this measure are relatively high, as food manufacturers are often willing to cooperate in exchange for incentives such as tax breaks or positive public relations (Public Health England 2017). However, despite the success of reformulation regarding sugar content reduction in SSB, it can be seen in the UK that consumers ate more high-sugar foods in 2019 and 2020 that had not been reformulated (e.g., chocolate) and fewer foods with the greatest sugar reductions (e.g., cereal and yogurt; Geldart 2023), decreasing the positive effect of sugar reduction.

Several nations have implemented *menu labelling regulations* to address obesity by providing consumers with calorie and nutritional information when making meal selections (Bleich, Economos, et al. 2017). The Food and Drug Administration (FDA) enacted countrywide menu labelling laws in the US in 2018, mandating that chain restaurants with 20 or more locations show calorie information on menus (Food and Drug Administration (FDA) 2019). The requirements are intended to help customers make educated food consumption decisions and to promote healthier eating habits. Some research suggests that providing customers with calorie information can result in minor decreases in their calorie intake (VanEpps et al. 2016).

Another approach that can be useful in promoting healthy eating habits is *public procurement of nutritious foods*. Governments can utilize their purchasing power to stimulate demand for healthier foods and encourage the food industry to offer healthier alternatives. In relation to the EU’s Farm to Fork Strategy, which aims to increase the availability and affordability of sustainable foods, actions include determining the most effective methods for establishing minimum mandatory criteria for sustainable food procurement in order to promote healthy and sustainable diets, including the consumption of organic products, in schools and public institutions (European Commission, n.d.).

Restrictions on general marketing, particularly advertisements that target children, can also be useful in reducing the intake of harmful foods. WHO has suggested that governments prohibit the marketing of harmful foods to children, citing evidence that such marketing promotes children's consumption of unhealthy foods. Concerns regarding freedom of expression and the potential economic impact on the food sector frequently limit the practicability of this approach (WHO 2010). A study found that exposure to harmful food advertising on television and the internet contributes to childhood obesity (Coleman et al. 2022).

Much attention has been paid to *workplace wellness programs* as a feasible method to promote employee health and well-being, particularly in combating the obesity epidemic. Generally, these programs try to encourage healthy habits, stimulate physical activity, and enhance nutritional choices among employees (Sutliffe et al. 2018). Research indicates that well-designed workplace wellness programs can enhance the body weight, overall health outcomes, and satisfaction of employees (Song and Baicker 2019). Effective programs frequently include components such as health risk assessments, individualized feedback, goal setting, and self-monitoring tools (Goetzel et al. 2014). In addition, these programs may involve environmental improvements in the workplace, such as providing healthier food options in cafeterias, designing areas for physical activity, and encouraging employees to take breaks for physical activity (Benedict and Arterburn 2008). Some companies also contribute to the cost of Gym memberships (Heinen and Darling 2009). The usefulness of workplace wellness programs is supported by a growing body of evidence. For example, a systematic review by Hutchinson and Wilson (2011) discovered that workplace interventions concentrating on food and physical activity can result in a slight reduction in body weight among employees, which is also supported by the results of a study by Schroer, Haupt, and Pieper (2013). Google's adoption of the "HealthWorks" program is one best-practice example of a successful workplace wellness program, offering an extensive array of interventions (Sullivan and Lachman 2017). The HealthWorks program has shown significant gains in employee health behaviors, with participants experiencing decreases in BMI, improvements in exercise levels, and increases in fruit and vegetable consumption (Sullivan and Lachman 2017). Although this is considered an example of best practice, it must be noted that it only targets a subset of individuals who have already achieved a higher socioeconomic status and therefore does not help to reduce inequality.

Active transportation policies, which encourage walking, bicycling, and the use of public transportation, are now recognized as excellent methods for boosting physical activity and avoiding obesity. Governments may play an important role in the implementation and promotion of these policies by investing in infrastructure, providing safe settings, and developing community activities that support active transportation (Sallis et al. 2016). The city of Copenhagen, for instance, has implemented a comprehensive active transportation policy that includes the development of a vast bicycle infrastructure and pedestrian-friendly urban planning, promoting active commuting. Thus, more than 60% of the city's residents commute by bicycle, contributing to higher levels of physical activity and lower obesity rates than places with less developed active transportation initiatives (City of Copenhagen 2019).

Obesity prevention and management involve *healthcare provider training and engagement*. By understanding obesity, healthcare providers may assist patients with weight management, and provide guidance and education about nutrition and exercise (Butsch et al. 2020). Governments and professional organizations generate and disseminate advice and tools for the prevention and treatment of obesity based on scientific data. The Centers for Disease Control and Prevention (CDC) of the US developed the "Preventing Pediatric Obesity in Primary Care" toolkit to assist healthcare professionals in effectively managing pediatric obesity (CDC 2019).

Schools play an essential role in developing the food habits of children and fostering a healthy lifestyle. Providing *school-based interventions* focusing on nutrition education, physical exercise, and access to healthy meals can be an effective strategy for preventing obesity (Bleich et al. 2018). The WHO suggests that schools develop a comprehensive approach that combines health-promoting activities throughout the curriculum, environment, and regulations (WHO 2017a). Several studies have demonstrated that multi-component school-based interventions can improve the eating habits, physical activity levels, and body weight of children (Wang et al. 2015; Wolfenden et al. 2014).

Public awareness initiatives, which have emerged as a significant approach for combatting the obesity epidemic by educating the population about healthy eating, physical activity, and the importance of maintaining a healthy weight, is another pertinent government action. Governments have a significant role in designing, sponsoring, and spreading these efforts to achieve maximum reach and impact (Lakshminarayanan 2011). A significant example is the UK's "Change4Life" campaign, launched by the Department of Health in 2009. This national public health campaign uses multiple communication channels, including television advertisements, print materials, and digital platforms, to encourage families to adopt healthier lifestyles, such as eating more fruits and vegetables, reducing their sugar intake, and engaging in more physical activity (Public Health England 2019). Evaluations of the Change4Life initiative have revealed that participants' awareness of healthy behaviors and dietary adjustments has grown significantly over the following ten years (Vohra et al. 2015).

Such *community-based interventions* to prevent obesity by involving individuals, families, and local organizations in healthier lifestyles have gained popularity. These projects address obesity determinants such as physical activity, diet, and the built environment through multisectoral collaboration between governments, non-governmental organizations, and community members (Economos and Hammond 2017).

Overall, education and awareness are essential mediators of the effectiveness of all of these policies. Education can assist individuals in making informed food choices and adopting healthier lifestyles. At least three factors are likely to determine the positive effect of education on obesity: greater access to health-related information and improved ability to process such information, a clearer perception of the risks associated with lifestyle choices, and improved self-control and consistency of preferences over time (Devaux et al. 2011). Policies such as soda taxes and FOP labelling can be difficult for individuals with low levels of education to understand. From the consumer's perspective, a soda tax can be perceived as a form of punishment due to the resulting increase in prices. Similarly, while not affecting the cost of the product, food labels may be difficult to understand, particularly if they are comprised solely of numerical values, such as the reference intake label (Tarabella and Voinea 2013). Conversely, if individuals comprehend the advantages of healthy eating, they are more likely to support policies such as soda taxes and food labelling, as well as demand healthier food options and adopt healthy eating practices. Thus, by investing in education as part of obesity prevention initiatives, governments and other stakeholders can help to address the root causes of obesity and improve population health outcomes.

4. Discussion

Obesity is a serious global issue that not only poses a significant health and wellbeing burden but also results in excessive health care costs. Governments play a vital role in combating obesity and employ a variety of measures to combat the disease. The most common are soda taxes and FOP labels and the bulk of the literature focuses on these, suggesting that soda taxes and FOP labels may be effective in preventing obesity and related NCD. However, their effectiveness may depend on factors such as the population targeted, the level of education, and the context of implementation.

The literature also has a few gaps. First, the majority of past research on soda taxes and FOP labels was conducted in a single nation, such as the US or Mexico, which may restrict the generalizability of the conclusions. Second, the majority of research focuses on a single policy, rather than investigating the effectiveness of multiple interventions in combination. Additional study is required to comprehend the efficacy of the policies in various contexts and combinations. Potentially, effectiveness would be maximized by implementing different, complementary policies simultaneously. Third, while the literature is able to show the effectiveness of some food policies in reducing the consumption of unhealthy foods and drinks, there is much less evidence of the outcome of the key interest, which is health. This is in part because health impacts take time to materialize, and attributing effects to the policies is challenging. Generally, studies do not use real-world data but instead rely on statistical modeling to estimate potential health impacts. Overall, the effectiveness of food policies on population health remains a promising area of study. Further research is needed on the long-term consequences of food policies, particularly their implications for chronic disease prevalence, as well as the interaction between different policy approaches and results.

According to Swinburn et al. (2019) and Hawkes et al. (2017), the need for effective food policies will increase as we continue to face challenges relating to health disparities, environmental sustainability, and food security. These include a larger emphasis on encouraging healthy as well as sustainable diets, a stronger focus on the role of food systems in combating climate change, and an ongoing emphasis on the need for equal access to good food.

Addressing access to healthy foods, research should investigate how policies might be formulated and implemented to alleviate health disparities and promote health equity. In contrast to, for example, workplace wellness programs, which are beneficial and effective in their (typically high-income) context, there must be initiatives from which a greater number of people from disadvantaged socioeconomic backgrounds can benefit. In addition, there is a need for research on the efficacy of food policies in low- and middle-income nations, where the incidence of food-related illnesses is frequently the highest (Hawkes et al. 2017). The potential health effects of future food technologies, such as lab-grown meat and plant-based alternatives, are also anticipated to receive increased attention. In addition to that, further research is necessary to explore lifestyle trends that mainly affect the population's mindset and food preferences despite implemented food policies.

With the implementation of food policies, such as soda taxes and FOP labelling requirements, population awareness, mindset, and consequently health can be improved. Despite the mentioned disadvantages and the controversy surrounding both policies and their effectiveness, the advantages outweigh the disadvantages, and governments should prioritize the effective implementation and combination of food policies in order to enhance population health.

The research questions addressed in the next two parts contribute to some of the identified research gaps in the following ways. First, we examine the relationship between both soda taxes and FOP labelling policies, and population health. Second, we investigate how governments utilize soda tax revenues for obesity prevention, informing about potential ways to enhance the benefits of soda taxes, while making soda taxes more progressive and more viable, politically.

Soda taxes, FOP labelling, and population health: a global longitudinal analysis

(Corinna Venker)

1. Introduction

To recap, the prevalence of overweight and obesity has increased dramatically in recent decades. Obesity is a complex health problem, often associated with other risk factors like high LDL cholesterol and high systolic blood pressure, all of which are key risk factors for type 2 diabetes and other NCD. The excessive consumption of SSB and other unhealthy foods is a major contributor to these health problems. To promote healthier food choices, governments have proposed several interventions; two of the most common are soda taxes and FOP labelling. This part of our thesis conducts an empirical exercise, using country-level panel data, to answer the research question *What is the association between the implementation of soda taxes and FOP labelling policies and population health?* In particular, we consider four population health-related outcomes: prevalence of overweight and obesity, type 2 diabetes, high LDL cholesterol, and high systolic blood pressure. This research addresses three main gaps previously identified. The first is a lack of evidence regarding the impacts of food policies such as soda taxes and FOP labelling requirements on the outcome of the main interest, which is population health. The second is that previous research was done in "siloes" considering each food policy in isolation. The third is the difficulty to compare and generalize findings from studies that focus on individual countries.

2. Methods

Using country-level data, we conducted panel regression analyses. The main specification is the following:

$$H_{it} = \alpha + \beta_1 ST_{it} + \beta_2 FOP_{it} + \gamma X_{it} + T_t + C_i + \varepsilon_{it} \qquad (1)$$

where H_{it} is one of the health outcomes described in the next section, e.g., rate of obesity in country i in year t. ST_{it} indicates if there is a soda tax in country i in year t, and FOP_{it} if there is a voluntary or mandatory FOP labelling policy. X_{it} is a vector of time-varying country-level factors that may confound the relationship between soda taxes, FOP labels, and health if unaccounted for. It includes GDP per capita, health expenditure per capita, rate of urbanization, and share of population above the age of 65. GDP per capita and health expenditure per capita enter the regression in natural logs, to account for their skewed distributions. The model includes a vector of time-fixed effects (T_t) for each of the years 2010-2019 that capture the effect of time in a flexible manner, and country-fixed effects (C_i) that capture country-specific characteristics more or less constant over time (e.g., cultural aspects related to diet or physical activity preferences, population preferences regarding government intervention). We are interested in the estimates of $\beta_1$and β_2, which give the association between e.g., the rate of obesity and the introduction of a soda tax or an FOP labelling policy.

In sensitivity analyses, we estimate the following alternative specification:

$$\Delta H_i = \alpha + H_{i,2010} + \beta_1 ST_{i,2019} + \beta_2 FOP_{i,2019} + \gamma \Delta X_i + \epsilon_i \qquad (2)$$

This is a cross-section regression analysis, with one observation per country, where Δ denotes the change between 2010 and 2019, $H_{i,2010}$ is the baseline health outcome, e.g., prevalence of obesity in 2010, and the variables of main interest, $ST_{i,2019}$ and $FOP_{i,2019}$, indicate if a country has yet implemented a soda tax or FOP labelling policy, as of 2019. We consider this alternative specification because the panel data models with country fixed effects rely only on within country variations; however, FOP labelling policies vary mainly between countries. So, while the panel data models have the advantage of controlling for time-invariant country characteristics through the inclusion of fixed effects (reducing bias from confounders), they may be subject to significant multicollinearity. Other sensitivity checks include the exclusion of outliers (top and bottom 5% of the distribution of the relevant health outcome) and restricting the sample to high-income countries, as these account for the majority of countries that implement soda taxes and FOP labelling policies.

3. Data

We collated annual country-level data, between 2010 and 2019, for all countries, from multiple sources (Table 2). We restricted the analysis to that time period because most soda taxes were implemented since 2010, and 2019 is the latest year available for the health outcomes. In addition, we limited the sample to 165 high-, upper-middle-, and lower-middle-income countries (WHO classification), excluding low-income countries because none of them have implemented soda taxes or FOP labelling policies. It is essential to note that low-income countries' populations tend to suffer from undernutrition rather than overnutrition, making food policies like the ones considered here potentially less pertinent. In addition, low-income countries face specific contextual obstacles, such as limited resources and infrastructure, which may hinder their ability to implement soda taxes or FOP labelling policies effectively.

3.1. Health outcomes

Data on the prevalence of overweight and obesity (BMI $\geq$ 25), type 2 diabetes, high LDL cholesterol, and high systolic blood pressure were retrieved from the Institute for Health Metrics and Evaluation Global Burden of Disease (IHME-GBD) Study 2019. These variables are measured as percentages of the adult population (ages 18+). GBD data are estimates based on sophisticated methods, as there are no survey or administrative data to allow the quantification of the various health measures for every country every year (Murray et al. 2020).

3.2. Soda taxes and FOP labelling policies

The UNC-Chapel Hill Global Food Research Program (2023) was the primary source of information on soda taxes and FOP labelling policies. In addition, alternative sources were reviewed to validate the year of implementation and other aspects (see Part 0). We created a binary variable where "0" indicates that soda taxes do not exist in a given country/year, while "1" indicates an existing soda tax, either single-tier or multi-tier. We did not distinguish between single- and multi-tier taxes given the relatively low number of country-year observations with a multi-tier tax. Similarly, for FOP labelling policies, a binary variable takes the value "0" if there are no FOP labelling rules in a given country and year, and "1" if there is a mandatory or voluntary FOP labelling policy. There weren't enough variations in the data to distinguish between mandatory or voluntary policies, or between different labels. Table 2 describes the remaining variables and their sources.

Table 2: Variables and sources

	Variable	***Data Source***	***Database***	***Definition***
Outcomes	**Overweight/ obesity**	IHME-GBD	Global Burden of Disease	Percentage of adults aged 18+ years with body mass index (BMI) of 25 kg/m2 or higher
Outcomes	**Diabetes**	IHME-GBD	Global Burden of Disease	Percentage of adults aged 18+ years with type 2 diabetes
Outcomes	**High Blood pressure**	IHME-GBD	Global Burden of Disease	Percentage of adults aged 18+ years with high systolic blood pressure
Outcomes	**High Cholesterol**	IHME-GBD	Global Burden of Disease	Percentage of adults aged 18+ years with high LDL cholesterol
Exposure variable	**Soda Tax**	UNC-Chapel Hill	Global Food Research Program	Presence or absence of a soda tax in a given country and year
Exposure variable	**FOP Labelling**	UNC-Chapel Hill	Global Food Research Program	Presence or absence of FOP labelling policy in a given country and year

Covariates	**GDP per capita**	World Bank	World Development Indicators	GDP divided by midyear population in constant 2020 international dollars (PPP)
Covariates	**% population living in urban areas**	World Bank	World Development Indicators	People living in urban areas, as defined by national statistical offices, in proportion of the total population
Covariates	**Health expenditure per capita**	World Bank	World Development Indicators	Current expenditures divided by midyear population in constant 2020 international dollars (PPP)
Covariates	**Population ≥ 65 years (%)**	World Bank	World Development Indicators	Population ages 65 and above as a percentage of the total population

Note: PPP = purchasing power parity.

4. Results

4.1. Descriptive statistics

Table 3 shows the descriptive statistics of included variables. On average, the prevalence of high BMI (i.e., overweight and obesity) is 25.54% (SD=9.04), ranging from 4.98 to 56.52. The prevalence of diabetes is 6.38% (SD=3.00) with a minimum of 1.90% and a maximum of 20.25%. High blood pressure affects 29.95% (SD=7.42) of the population, on average, with a range of 12.73% to 47.44%. High cholesterol is observed in 35.95% (SD=9.67) of the population, on average, with a minimum of 8.40% and a maximum of 57.30%.

A soda tax is implemented in 11% of the country-years, and FOP labelling in 14%. Regarding the covariates, health expenditure per capita averages 1,507.66 international (i.e., PPP) dollars (SD=1,666.73), ranging from 59.24 to 10,661.03. The average GDP per capita is 22,334.20 international dollars (SD=24,072.35), with a minimum of 1,623.98 and a maximum of 211,326.50, excluding low-income countries. Urban population accounts for 61.66% (SD=21.97) of the total population, on average, ranging from 12.98% to 100%. Finally, the population aged 65 years and over represents 9.04% (SD=6.20) of the total population, on average, with a minimum of 0.18% and a maximum of 35.62%.

Table 3: Descriptive statistics of included variables

Variables	N	Mean	Standard Deviation	Min	Max
High BMI (%)	1,650	25.54	9.04	4.98	56.52
Diabetes (%)	1,650	6.38	3.00	1.90	20.25
High Blood Pressure (%)	1,650	29.59	7.42	12.73	47.44
High Cholesterol (%)	1,650	35.95	9.67	8.40	57.30
Soda Tax	1,650	0.11	0.32	0	1
FOP labelling	1,650	0.14	0.34	0	1
Health Expenditure per capita ($ PPP)*	1,639	1,507.66	1,666.73	59.24	10,661.03
GDP per capita ($ PPP)*	1,649	22,334.20	24,072.35	1,623.98	211,326.50
Urban Population (%)	1,650	61.66	21.97	12.98	100.00
Population ≥ 65 years (%)	1,650	9.04	6.20	0.18	35.62

**Enters the regression in natural logs. PPP=purchasing power parity.*

Figures 3 and 4 show the development of the four health outcomes between 2010 (xx axis) and 2019 (yy axis) in each of the 165 countries. As observed from the majority of circles located above the 45º line, the prevalence of all health issues, especially diabetes and overweight and obesity, increased over the sample period in a large majority of countries.

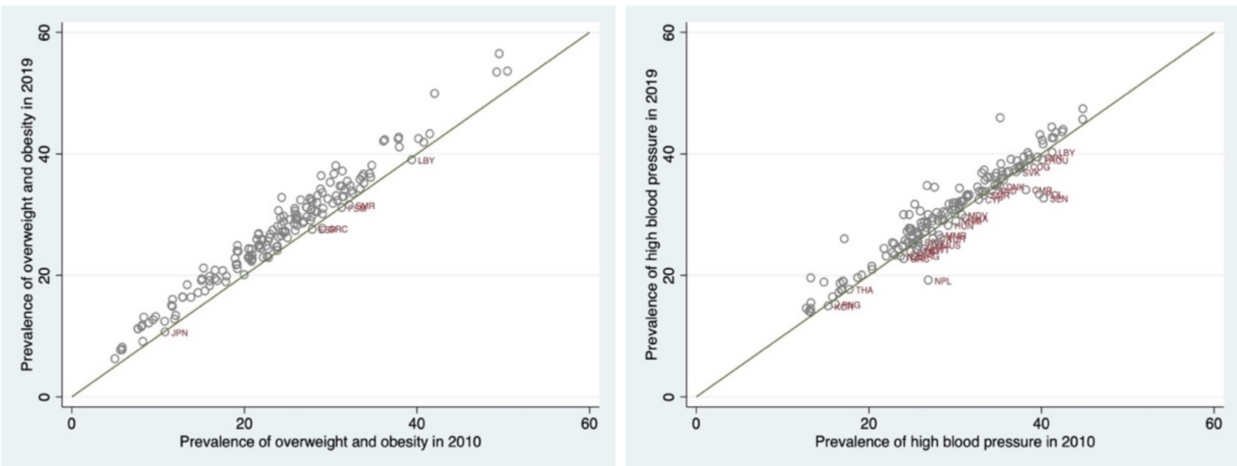


Figure 3: Changes in health outcomes between 2010 and 2019 (1)

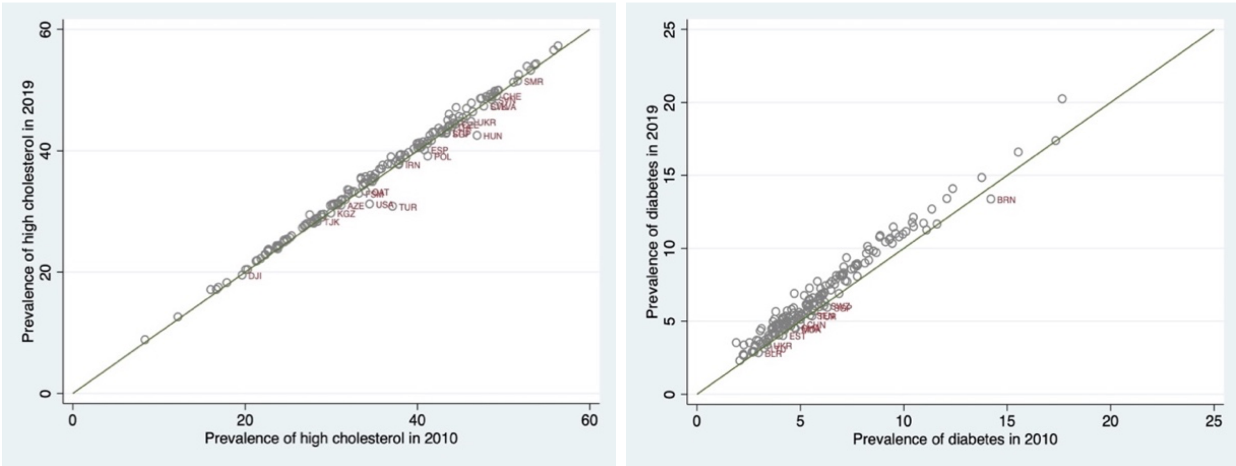


Figure 4: Changes in health outcomes between 2010 and 2019 (2)

Note: labeled countries are those below the 45° line. For ease of presentation, the bottom-right plot has a different scale, as the prevalence of diabetes is lower than that of other health issues.

4.2. Main results

Table 4 shows the results of estimating equation (1) for each of the four health outcomes. Primarily, results indicate that implementing a **soda tax** has a negative association with the prevalence of overweight and obesity. Specifically, the coefficient indicates a prevalence of overweight and obesity that is on average lower by 0.257 percentage points when countries introduce a soda tax. Against expectations, we do not find a statistically significant association between the implementation of soda taxes and the prevalence of type 2 diabetes or high cholesterol, and we find a positive association between soda taxes and the prevalence of high blood pressure. There is limited prior evidence on the effect of soda taxes on the prevalence of type 2 diabetes and even less on risk factors like high blood pressure and cholesterol. Nevertheless, some studies found a significant negative association between soda taxes and the prevalence of diabetes, suggesting that the relationship between soda taxes and diabetes and other health outcomes is complex and may depend on additional factors not included here, such as the design and context of the implementation of the tax (Harvard T.H. Chan School of Public Health 2016).

Table 4: Main results (panel analysis)

	High BMI	Diabetes	High Blood Pressure	High Cholesterol
Soda Tax	-0.257***	0.015	0.231**	-0.068
	(0.079)	(0.032)	(0.112)	(0.052)
FOP labelling	0.010	-0.038	0.077	0.090
	(0.090)	(0.036)	(0.127)	(0.059)
Ln (Health Expenditure pc)	1.253***	0.068	-0.751***	0.167*
	(0.140)	(0.056)	(0.197)	(0.091)
Ln (GDP pc)	-1.466***	0.216***	0.214	-0.401***
	(0.159)	(0.064)	(0.225)	(0.104)
Urban Population	0.079***	-0.010	0.087***	0.010
	(0.016)	(0.007)	(0.023)	(0.011)
Population 65+	-0.364***	-0.060***	-0.173***	-0.108***
	(0.030)	(0.012)	(0.043)	(0.020)
2010	Baseline			
2011	0.353***	0.081***	0.069	0.034
	(0.061)	(0.025)	(0.086)	(0.040)
2012	0.716***	0.174***	0.183**	0.078*
	(0.063)	(0.026)	(0.090)	(0.041)
2013	1.101***	0.270***	0.327***	0.135***
	(0.067)	(0.027)	(0.095)	(0.044)
2014	1.500***	0.364***	0.479***	0.199***
	(0.072)	(0.029)	(0.101)	(0.047)
2015	1.879***	0.452***	0.645***	0.262***
	(0.076)	(0.031)	(0.107)	(0.050)
2016	2.265***	0.523***	0.822***	0.341***
	(0.082)	(0.033)	(0.116)	(0.053)
2017	2.702***	0.592***	1.004***	0.445***
	(0.089)	(0.036)	(0.126)	(0.058)
2018	3.117***	0.688***	1.188***	0.568***
	(0.097)	(0.039)	(0.137)	(0.063)
2019	3.511***	0.822***	1.385***	0.708***
	(0.105)	(0.043)	(0.149)	(0.069)
N	1639	1639	1639	1639

*Notes: standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Contrary to prior studies, which have found that FOP labelling policies may reduce the consumption of unhealthy foods and contribute to improving population health, this regression analysis revealed no association between **FOP labelling** introduction and any of the four outcomes considered ($p > 0.1$). Nevertheless, studies have also shown that FOP labelling is not always effective, e.g., because label misinterpretation could result in confusion (Ferguson 2022; Part 0). Additionally, given that in most countries, FOP labelling is voluntary, and over the period of analysis, few countries implemented FOP labels (most already had them in 2010), these could also explain the lack of a significant association.

We are cautious with the interpretation of the coefficients associated with covariates, which are generally not consistent in sign across the four models and sometimes have counterintuitive signs. For example, **health expenditure** is a potentially endogenous variable. On the one hand, higher investments in health (e.g., implementing community-based programs to monitor the risk factors for NCD, like high cholesterol and blood pressure) may contribute to improving population health, although such investments may take several years to produce improvements. On the other hand, a higher prevalence of obesity, diabetes, high blood pressure, and cholesterol may cause additional health expenditures (i.e., reverse causality). For instance, the influence of obesity and diabetes on medical costs in the US is substantially more than anticipated (Cawley and Meyerhoefer 2012; American Diabetes Association 2018).

Regarding **GDP**, economic development is frequently accompanied by either positive and negative lifestyle changes, including e.g., trends in fitness and healthy eating, or increased consumption of processed and energy-dense foods (Popkin et al. 2012), depending on countries' starting points along the "nutrition transition".

We find the correlation between **urbanization** and the prevalence of obesity and high blood pressure to be statistically significant and positive, but no correlation with diabetes and high cholesterol rates. Recent research indicates that urbanization —with its associated lifestyle changes— is a major contributor to the global increase in obesity and diabetes (Popkin 2017; Giles-Corti et al. 2016). Remaining endogeneity and omitted factors in the complex relationship between urbanization and the health outcomes considered may underlie the lack of a consistent negative relationship throughout our analyses.

The estimated correlation between the proportion of the **population aged 65 and older** and the prevalence of obesity, diabetes, high blood pressure, and cholesterol, is consistently negative and statistically significant. This appears counterintuitive as older populations tend to have a higher prevalence of these conditions (Flegal et al. 2012; Mitchell et al. 2012). However, ageing populations may be accompanied by better healthcare systems, public health initiatives, prevention programs, NCD monitoring (Bloom et al. 2015), which may not be fully captured by the health expenditure variable included in the regression. Lastly, the year dummies are positive and growing in magnitude, indicating a growing prevalence of all four conditions over time, in line with the plots in Figure 3.

4.3. Sensitivity analysis

Appendix 2 shows the summary statistics of all variables in 2010 and in 2019, which are used to construct the cross-sectional dataset, with variables measured in differences, for the estimation of equation (2). Focusing on the key variables of interest, the proportion of countries with a soda tax rose from 4% to 22%, while FOP labelling policies were in place in 20% of the observed countries in 2019, compared to 8% in 2010.

Table 5 shows the results of estimating equation (2) for each of the four health outcomes. The findings of this cross-sectional analysis are generally consistent with those of the panel analysis, despite some differences in statistical significance and magnitudes of coefficients, attributable to the difference in measurement scale. Regarding the two policies of interest, the only statistically significant association ($p < 0.1$) is that between having implemented a soda tax by 2019 and a change in diabetes prevalence. Interestingly (and alarmingly), the analysis shows that nations with a one percentage point higher prevalence of overweight/obesity (diabetes) in 2010 had a 0.03 (0.05) percentage point increase by 2019, indicating that countries with worse population health, as measured by these two variables, at baseline, also saw worse trajectories until 2019.

Table 5: Results of the cross-section analysis

	Change in High BMI	**Change in Diabetes**	**Change in High Blood Pressure**	**Change in High Cholesterol**
High BMI 2010	0.033**			
	(0.014)			
Diabetes 2010		0.050**		
		(0.024)		
High Blood Pressure 2010			-0.053**	
			(0.025)	
High Cholesterol 2010				0.007
				(0.008)
Soda Tax 2019	-0.256	0.199*	0.145	-0.016
	(0.329)	(0.118)	(0.337)	(0.218)
FOP labelling 2019	0.056	-0.137	0.051	-0.154
	(0.281)	(0.136)	(0.368)	(0.188)
Change in ln (Health Expenditure pc)	1.387***	0.023	-1.570**	0.240
	(0.469)	(0.172)	(0.639)	(0.249)
Change in ln (GDP pc)	-0.886	0.220	0.789	-0.478
	(0.682)	(0.231)	(0.774)	(0.367)
Change in Urban Population	0.104**	-0.005	0.094	0.015
	(0.048)	(0.017)	(0.059)	(0.027)
Change in Population 65+	-0.397***	-0.025	-0.191*	-0.120**
	(0.102)	(0.030)	(0.113)	(0.058)
N	161	161	161	161

*Notes: standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Returning to panel data analyses, a further sensitivity check was carried out in which outliers were removed, i.e., only values within the 5-95 percentiles of the distribution of each health outcome were examined (Appendix 1). Overall, the results are in line with the previous main results, with some changes in significance in the case of soda tax implementation. FOP labelling continues to have no association with any of the outcomes considered. The stronger association observed between soda tax implementation and the prevalence of overweight and obesity is also observed here.

Finally, a sensitivity analysis was conducted considering only high-income nations (Table 6). This is done because most of the policy action has taken place in high-income countries, where the proportion of country-year observations with a soda tax (FOP labelling policy) is 16% (28%) compared with 11% (14%) in the main sample, as well as to obtain a more homogeneous sample. In this subsample, we no longer observe a significant negative correlation between implementing a soda tax and obesity prevalence. It appears that that result was driven by middle-income countries, such as Mexico and Ecuador. In turn, we observe a significant negative correlation between the implementation of soda taxes in high-income countries and the prevalence of diabetes and high cholesterol and a positive association with the prevalence of high blood pressure. Additionally, there is a negative correlation between the introduction of FOP labelling in high-income countries and the prevalence of overweight and obesity and a positive correlation with the prevalence of high cholesterol. Although causality claims are not made here, these results illustrate the heterogeneity of food policies and their potential effects across nations.

Table 6: Sensitivity analysis: Only high-income countries

	High BMI	Diabetes	High Blood Pressure	High Cholesterol
Soda Tax	-0.031	-0.125**	0.591***	-0.242***
	(0.118)	(0.056)	(0.123)	(0.086)
FOP labelling	-0.198*	-0.054	-0.000	0.195**
	(0.110)	(0.052)	(0.114)	(0.080)
Ln (Health Expenditure pc)	2.463***	0.042	0.306	0.011
	(0.304)	(0.143)	(0.316)	(0.221)
Ln (GDP pc)	-1.942***	0.552***	0.662**	-0.581***
	(0.264)	(0.124)	(0.274)	(0.191)
Urban Population	-0.070*	0.052***	0.120***	0.042
	(0.037)	(0.018)	(0.039)	(0.027)
Population 65+	-0.407***	-0.094***	-0.217***	-0.144***
	(0.049)	(0.023)	(0.051)	(0.035)
2010	Baseline			
2011	0.362***	0.066	-0.001	0.004
	(0.101)	(0.048)	(0.105)	(0.074)
2012	0.696***	0.160***	0.044	0.029
	(0.106)	(0.050)	(0.110)	(0.077)
2013	1.065***	0.250***	0.129	0.066
	(0.114)	(0.054)	(0.119)	(0.083)
2014	1.429***	0.341***	0.234*	0.120
	(0.126)	(0.059)	(0.131)	(0.091)
2015	1.724***	0.433***	0.366**	0.188*
	(0.138)	(0.065)	(0.144)	(0.101)
2016	2.023***	0.475***	0.494***	0.277**
	(0.153)	(0.072)	(0.159)	(0.111)
2017	2.397***	0.525***	0.606***	0.400***
	(0.168)	(0.079)	(0.174)	(0.122)
2018	2.777***	0.642***	0.741***	0.553***
	(0.183)	(0.086)	(0.190)	(0.133)
2019	3.126***	0.830***	0.908***	0.734***
	(0.202)	(0.096)	(0.210)	(0.147)
N	569	569	569	569

*Notes: standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

5. Discussion

This study examined the association between soda taxes and FOP labelling and obesity, diabetes, high blood pressure, and cholesterol. The results indicate that soda taxes are significantly and negatively associated with the prevalence of overweight and obesity, but this result is driven by middle-income countries and does not stand in a sample of high-income countries only. Conversely, we find a negative association between soda taxes and diabetes prevalence only in high-income countries. This is somewhat consistent with previous research that has linked soda taxes to decreased consumption of sugary drinks and positive health outcomes, including lower rates of obesity and type 2 diabetes (e.g., Ferretti and Mariani 2019, Falbe et al. 2016, Briggs et al. 2017). However, the relationship between soda taxes and health is complex, takes time to materialize, and may depend on additional factors not accounted for in our analyses (Harvard T.H. Chan School of Public Health 2016).

FOP labelling shows no association with the health outcomes considered, except for the prevalence of overweight and obesity in the subsample of high-income countries. The literature indicates that FOP labelling may be useful in reducing sugar intake and the prevalence of obesity (Taillie et al. 2020) and diabetes prevalence (Andreeva et al. 2021). However, as discussed in Part 0, the efficacy of FOP labels may depend on a variety of factors, including the label's design and format, individual characteristics such as health literacy, dietary patterns, other food policies that may be in place, food industry responses, etc. (Croker et al. 2020; Kanter et al. 2018; Roberto et al. 2021). Additionally, it is important to note that in most countries, FOP labels remain voluntary.

This study has several limitations. One significant limitation is its observational nature, which makes it challenging to establish a causal relationship between soda taxes, labels, and population health. Variables such as cultural traits related to diet and exercise, other food policies, marketing and advertising of harmful foods and beverages, and other industry actions, may explain obesity and diabetes and may also have a relationship with soda taxes and FOP labelling. These factors may vary within countries over time and not be captured by the country-fixed effects (i.e., remaining confounders). For example, governments may be more prone to introduce soda taxes if dietary habits of the population are particularly concerning or if the industry requires incentives to improve the nutritional value of their products. They are also more prone to adopt food policies if population health is worse (i.e., reverse causality).

The second main limitation of this thesis is its reliance on GBD data. The GBD study offers estimates rather than direct measurements of the variables under consideration. These estimates are derived using complex modeling techniques and data from multiple sources, such as surveys, administrative registries, and published studies. While GBD estimates are widely recognized for their comprehensiveness and methodological rigor, they are susceptible to inherent uncertainties and potential biases due to data gaps, varying data quality, and estimation process assumptions. Therefore, the findings of this thesis should be carefully interpreted. Also, as GBD data are estimates, they are inherently "smoothed", i.e., there are fewer variations to use in the statistical analyses. Future research utilizing primary data sources would bring additional value but was unfeasible in the context of this thesis.

Despite these limitations, our research makes a first attempt to relate food policies to population health by adopting a global approach, contributing to the literature which is mostly focused on intermediate outcomes (i.e., consumption of unhealthy foods and beverages) and on single countries. Future research building on our analysis, e.g., by using primary data sources and controlling for additional variables, may bring additional value to the global obesity policy discussion, and help policymakers evaluate existing policies and develop new ones to enhance population health and reduce the burden of NCD.

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Appendix

	High BMI	Diabetes	High Blood Pressure	High Cholesterol
Soda Tax	-0.227***	0.055*	0.119	-0.097*
	(0.085)	(0.032)	(0.115)	(0.055)
FOP labelling	0.005	0.024	0.010	0.084
	(0.089)	(0.037)	(0.133)	(0.065)
Ln (Health Expenditure pc)	1.278***	-0.006	-0.765***	0.217**
	(0.157)	(0.056)	(0.202)	(0.099)
Ln (GDP pc)	-0.946***	0.066	0.044	-0.418***
	(0.184)	(0.065)	(0.230)	(0.111)
Urban Population	0.115***	-0.018***	0.081***	0.010
	(0.018)	(0.007)	(0.024)	(0.012)
Population 65+	-0.342***	-0.076***	-0.176***	-0.143***
	(0.031)	(0.012)	(0.044)	(0.023)
2010	Baseline			
2011	0.310***	0.092***	0.077	0.033
	(0.064)	(0.025)	(0.088)	(0.044)
2012	0.636***	0.200***	0.197**	0.077*
	(0.066)	(0.025)	(0.092)	(0.045)
2013	0.987***	0.310***	0.345***	0.134***
	(0.070)	(0.027)	(0.097)	(0.048)
2014	1.355***	0.413***	0.500***	0.201***
	(0.075)	(0.029)	(0.104)	(0.051)
2015	1.725***	0.507***	0.656***	0.269***
	(0.080)	(0.031)	(0.110)	(0.054)
2016	2.082***	0.592***	0.802***	0.354***
	(0.086)	(0.033)	(0.118)	(0.058)
2017	2.479***	0.675***	0.988***	0.470***
	(0.095)	(0.036)	(0.129)	(0.063)
2018	2.835***	0.784***	1.174***	0.603***
	(0.104)	(0.039)	(0.140)	(0.069)
2019	3.212***	0.924***	1.377***	0.751***
	(0.113)	(0.043)	(0.152)	(0.075)
N	1474	1473	1474	1473

*Notes: standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

Appendix 1: Sensitivity analysis: No outliers

Variables	N	Mean	Standard Deviation	Min	Max
High BMI 2010	165	24.01	8.84	4.98	50.49
High BMI 2019	165	27.09	9.15	6.28	56.52
Diabetes 2010	165	6.00	2.88	1.90	17.66
Diabetes 2019	165	6.79	3.10	2.30	20.25
High Blood Pressure 2010	165	29.08	7.44	12.74	44.80
High Blood Pressure 2019	165	30.27	7.45	13.98	47.44
High Cholesterol 2010	165	35.77	9.75	8.40	56.32
High Cholesterol 2019	165	36.28	9.73	8.86	57.30
Soda Tax 2010	165	0.04	0.20	0	1
Soda Tax 2019	165	0.22	0.42	0	1
FOP labelling 2010	165	0.08	0.27	0	1
FOP labelling 2019	165	0.20	0.40	0	1
Ln (Health Expenditures pc) 2010	164	6.53	1.19	4.08	8.97
Ln (Health Expenditures pc) 2019	162	6.88	1.19	4.34	9.27
Ln (GDP pc) 2010	164	9.39	1.03	7.39	11.87
Ln (GDP pc) 2019	165	9.70	0.96	7.69	12.26
Urban Population 2010	165	60.29	22.07	13.02	100
Urban Population 2019	165	63.01	21.91	13.25	100
Population 65+ 2010	165	8.32	5.62	0.18	27.37
Population 65+ 2019	165	9.89	6.68	1.17	35.62

Appendix 2: Summary statistics, 2010 vs. 2019