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Tax as a Public Health Policy

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Abstract

Over the last decades, there is a global increase in diet-related diseases. Among the health consequences of unhealthy diets with excess calorie intake is obesity, which is increasing rapidly and it is a major risk factor for cardiovascular and metabolic diseases. Diet-related health problems lead to economic problems of direct healthcare costs and indirect costs of lost productivity due to morbidity and early mortality.

This thesis gives the first estimates of the economic costs of unhealthy diet and high body-mass index (i.e., overweight and obesity) in Greece. I estimate that these costs were equal to 2.52% and 2.00% of GDP, respectively, in 2017. To put matters into perspective, the economic cost of smoking and second hand smoke exposure is also estimated, as tobacco use is the leading risk factor for deaths and years lived with disability in Greece. The tobacco use cost was estimated at 3.85% of GDP.

These large economic consequences of preventable disease risk factors, on top of the more obvious impacts on population health, motivate policy interventions. Governments could tax unhealthy goods and use the revenue to finance complementary policies, such as subsidies for healthy goods, information campaigns etc. This thesis examines the role of fiscal policies for public health purposes. I consider the optimal tax on unhealthy goods, with and without distributional considerations, and how it is affected by the way the tax revenue is used (returned as a lump sum transfer or earmarked to subsidise a healthy good). Without distributional concerns, the way the revenue is used does not affect the tax rate. With distributional concerns, the tax rate is lower (for both schemes of revenue use) and the subsidy rate is higher compared to the case of no distributional concerns. If government has as a priority the health improvement, it should implement a combined tax – subsidy policy with no distributional concerns.

I also estimate effects of taxes and subsidies on consumption of unhealthy and healthy goods in Greece. As a first step, using data for 2019, own- and cross-price elasticities are estimated for thirteen food and beverages categories. Then, these elasticities are used to simulate effects of different fiscal policies on food consumption. The policies include a 20% tax on soft drinks and/or sweets, a subsidy on fruit and vegetables equivalent to a zero value added tax (VAT), and a combined tax-subsidy policy. The combined tax-subsidy policy has a great impact on their demand, as tax policy enhances the effect of the subsidy policy, and vice versa.

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Abbreviations

AIDS	Almost Ideal Demand System
BMI	Body Mass Index
COI	Cost of Illness Approach
CSD	Carbonated Soft Drinks
CVD	Cardiovascular Diseases
DARA	Decreasing Absolute Risk Aversion
ELSTAT	Hellenic Statistical Authority
EU	European Union
EUROSTAT	European Statistical Office
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FCTC	Framework Convention on Tobacco Control
GBD	Global Burden Disease Study
GDP	Gross Domestic Product
HBS	Household Budget Survey
IHME	Institute of Health Metrics and Evaluation
IMF	International Monetary Fund
LES	Linear Expenditure System
MQS	Minimum Quantity Standards
OECD	Organisation for Economic Co-operation and Development
PVLE	Present Value of Lifetime Earnings
QAIDS	Quadratic Almost Ideal Demand System
RAF	Attributable Fraction due to a Risk Factor
SAE	Smoking-attributable healthcare expenditure
SHS	Secondhand Smoke
SSB	Sugar Sweetened Beverages
VAT	Value Added Tax
WHO	World Health Organization
YLD	Years Lived with Disability

Introduction

Since 1975, the worldwide prevalence of obesity has increased about three times for adults and more than eight times for children (WHO, 2017). Greece has also followed this trend, ranked, among the EU countries, first and third on the prevalence of overweight children and adults, respectively (WHO, 2017).

Overweight and obesity are risk factors for several serious chronic diseases (e.g., diabetes) which, in turn, lead to a series of financial problems. Specifically, obese people need medication and treatments which increase healthcare expenditures. Additionally, excess weight imposes indirect costs on society through production losses arising from attributable morbidity and premature mortality.

To combat the obesity pandemic, it is crucial to understand its causes. Genetic factors cannot explain the great increase in obesity and overweight rates over the last decades (Cremer et al., 2016; Hill and Peters, 1998). Behavioural and environmental factors, such as unhealthy diet and moderate physical activity, are those which affect the energy balance and lead to increasing excess weight (Hill, 2006; WHO, 2022). Thus, policies aiming at preventing and combatting obesity should focus on improving diet and physical activity. In Greece, diet is a more serious risk factor than physical activity (Global Burden of Disease Collaborative Network, 2020). For that reason, we focus on policies targeting dietary habits and specifically on fiscal policies (i.e., taxes on unhealthy goods and subsidies on healthy goods).

The aim of this thesis is twofold. First, it highlights the financial consequences of unhealthy diet and high body mass index (BMI) by estimating the economic costs of these risk factors in Greece. Second, it examines optimal design of fiscal policies to combat obesity and uses the results to propose a fiscal policy for Greece. A comparison with tobacco use is also made because this is the leading behavioural risk factor for the burden of disease in Greece and successful smoking prevention policies have already been implemented.

This thesis is divided in three parts. Part A consists of two chapters and describes the background and motivation. Specifically, Chapter 1 presents evidence on eating habits and prevalence of overweight and obesity, as well as, on tobacco use in Greece. The health and financial consequences of the aforementioned risk factors and policies to combat obesity and tobacco use are also discussed. In

Chapter 2, the focus is on fat taxes as an obesity-combating policy. It provides a discussion on the countries which have already implemented a fat tax, as well as global studies related to the topic.

Part B is concerned with the economic cost of risk factors. Chapter 3 provides the methodology and the data used to estimate the economic cost of risk factors in Greece and a literature review. Chapters 4 presents the results of the study on the economic cost of dietary risks and high body-mass index. The economic cost of smoking and second-hand smoking (SHS) exposure is also estimated and results are shown in Chapter 5. In both Chapters 4 and 5, the focus is on costs in 2017 with brief results also shown for 1997 and 2007. In Chapter 6, results of the economic cost studies are discussed and conclusions are made.

Part C is about fiscal policies for public health. In Chapter 7, I use theory to examine the optimal fiscal policy when individuals misperceive the negative health consequences of unhealthy eating and/or the benefits of healthy consumption. It is assumed that government taxes the unhealthy good and chooses how to spend the resulting revenue, either returning it to consumers as a lump sum or subsidising the consumption of a healthy good. In both cases, the optimal design is analyzed with and without distributional concerns. In Chapter 8, demand for food and beverages in Greece is examined, estimating own-and cross-price elasticities for year 2019. Based on these estimates, I calculate the effect of different fiscal policies on food and beverage demand. The policies under consideration include a 20% tax on soft drinks and/or sweets, a subsidy on fruit and vegetables equivalent to a zero value added tax (VAT), and a combination of the above-mentioned policies. Chapter 9 presents the conclusions of the study and suggestions for further research.

PART A: Background and Motivation

The first Part of this thesis presents the motivation and the background. Specifically, Chapter 1 provides evidence related to obesity problem in Greece. It starts with the Greek dietary habits, which is a main determinant of obesity, and the prevalence of overweight and obesity. To highlight the consequences, we present data on deaths and disability related to dietary risks and high BMI and we mention the financial consequences. Chapter 1 continues with the presentation of the policies available to combat and prevent obesity. For comparison purposes, we also discuss evidence on tobacco as well as the tobacco policies given that tobacco use is a primer risk factor for disease.

Among the different policies, our interest is on fiscal policies. Thus, in Chapter 2, we report the countries which have already implemented taxes on unhealthy goods and present studies related to such policies.

Chapter 1: Fiscal Incentives and Healthy Behaviour

So-called "sin goods" – alcohol, tobacco, fast foods, sugary foods and soft drinks – are claimed to harm social welfare. Unhealthy foods, which are linked to increased BMI, and tobacco use are of great concern to Greece.

1.1 Evidence on Dietary Habits, Overweight/Obesity and Tobacco Use in Greece

1.1.1 Dietary Habits

Greece is well known for the Mediterranean diet which is one of the healthiest diets. It is based on daily consumption of cereals, pulses, fruit, vegetables and olive oil, moderate consumption of dairy, fish and white meat, and limited consumption of red meat and sweets. With globalization and the modern pace of life, however, Greeks moved away from the Mediterranean diet, adopting more unhealthy eating habits. One way to examine the change in dietary habits is to analyze the food supply[1] measured both in per capita daily quantity and calories. As it is shown in Table 1.1, between 1961 and 2019, total food supply grew by 20.3%, from 2824 kcal/capita/day to 3396 kcal/capita/day. About 77% - 85% of food supply is cereals, vegetable oils, milk, meat, sugar and fruits. In 2019, the only food categories with lower availability, compared to 1961, were cereals, pulses and fruits. Just for cereals, however, the reduction was vital as, in 1961, their availability was 47% of total food supply while in 2019 the proportion dropped to 26,2% (a 437 kcal/capita/day reduction). For the remaining categories, the increase in supply is great for meat (224.7%) and milk (122.2%), but also for vegetable oils (60.8%) and sugar (93.2%).

Based on the latest data (2019), food supply for vegetable oils, milk, fruits, treenuts and oilcrops is higher in Greece than world and Europe. Moreover, food availability is greater for meat and sugar, compared to the world average, and it is slightly higher for pulses and vegetables, compared to Europe (see Graph A.1.1, in Appendix A1). It is well noticed that supply for vegetable oils is much higher in

[1] It is the total amount of the commodity available as human food during the reference period. It includes the commodity in question, as well as any commodity derived therefrom as a result of further processing (e.g., milk relates to the amounts of milk as such, as well as the fresh milk equivalent of dairy products).

Greece than in world and Europe. At the same time, the opposite occurs for animal fat supply. This is a key characteristic of the Mediterranean diet where olive oil is used as the main fat product. Summing vegetable oils and animal fats, the total supply of these products is more than double the worldwide corresponding supply and close to the European one.

Table 1.1: Food Supply in kcal/capita/day, total and by category, 1961 and 2019, Greece

	1961		2019		1961 - 2019	
	Supply	**Distri-bution**	**Supply**	**Distri-bution**	**Change**	**% Change**
Grand Total	**2824**	**100.0%**	**3396**	**100.0%**	**572**	**20.3%**
Vegetal Products	**2450**	**86.8%**	**2553**	**75.2%**	**103**	**4.2%**
Cereals	1327	47.0%	890	26.2%	-437	-32.9%
Starchy Roots	59	2.1%	104	3.1%	45	76.3%
Sugar & Sweeteners	148	5.2%	286	8.4%	138	93.2%
Pulses	74	2.6%	32	0.9%	-42	-56.8%
Treenuts	43	1.5%	64	1.9%	21	48.8%
Oilcrops	23	0.8%	70	2.1%	47	204.3%
Vegetable Oils	423	15.0%	680	20.0%	257	60.8%
Vegetables	68	2.4%	93	2.7%	25	36.8%
Fruits	200	7.1%	184	5.4%	-16	-8.0%
Stimulants	2	0.1%	30	0.9%	28	1400.0%
Spices	2	0.1%	5	0.1%	3	150.0%
Alcoholic Beverages	80	2.8%	105	3.1%	25	31.3%
Miscellaneous	1	0.0%	11	0.3%	10	1000.0%
Animal Products	**375**	**13.3%**	**843**	**24.8%**	**468**	**124.8%**
Meat	93	3.3%	302	8.9%	209	224.7%
Offals	7	0.2%	12	0.4%	5	71.4%
Animal fats	36	1.3%	52	1.5%	16	44.4%
Milk - Excluding Butter	185	6.6%	411	12.1%	226	122.2%
Eggs	22	0.8%	33	1.0%	11	50.0%
Fish, Seafood	31	1.1%	34	1.0%	3	9.7%

Source: FAOSTAT (FAO, 2021, 2022a)
Note: Data have been estimated with the new methodology since 2010.

The caloric food supply corresponds to a specific quantity for each food category. As it is shown in Table 1.2, in 2019, the per capita daily availability was 629.6 gr for milk, 218.9 gr for meat, 79.5 gr for vegetable oils and 92.4 for sugar. Quantity for cereals and starchy roots was 347.1 gr and 165 gr, respectively, while for fruits and vegetables the amount is almost the same, about 400 gr.

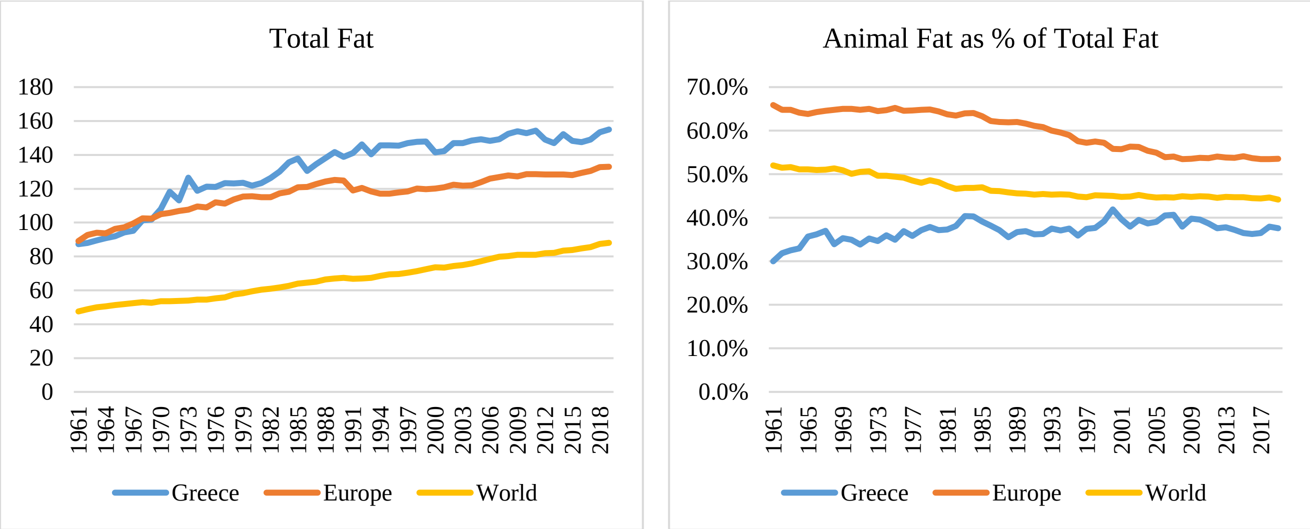
Table 1.2: Food Supply in grams/capita/day, by food category, 1961 and 2019, Greece

			1961 - 2019	
	1961	**2019**	**Change**	**% Change**
Vegetal Products				
Cereals	457.0	347.1	-109.9	-24.0%
Starchy Roots	87.7	165.0	77.3	88.1%
Sugar & Sweeteners	41.9	92.4	50.6	120.8%
Pulses	21.6	9.5	-12.1	-55.8%
Treenuts	22.8	30.7	7.9	34.7%
Oilcrops	16.8	54.4	37.6	223.7%
Vegetable Oils	47.9	79.5	31.7	66.2%
Vegetables	313.8	411.5	97.6	31.1%
Fruits	365.8	394.4	28.7	7.8%
Stimulants	3.4	12.5	9.0	264.0%
Spices	0.6	1.4	0.8	147.6%
Alcoholic Beverages	110.4	158.3	47.9	43.4%
Miscellaneous	0.2	2.9	2.7	1650.0%
Animal Products				
Meat	57.7	218.9	161.2	279.3%
Offals	6.2	9.3	3.2	50.9%
Animal fats	5.3	10.1	4.9	92.7%
Milk - Excluding Butter	276.5	629.6	353.1	127.7%
Eggs	15.6	23.1	7.5	47.9%
Fish, Seafood	44.5	53.8	9.3	20.9%

Source: Own calculations based on data on food supply (in kg/capita/year) from FAOSTAT (FAO, 2021, 2022a)
Note: Data have been estimated with the new methodology since 2010.

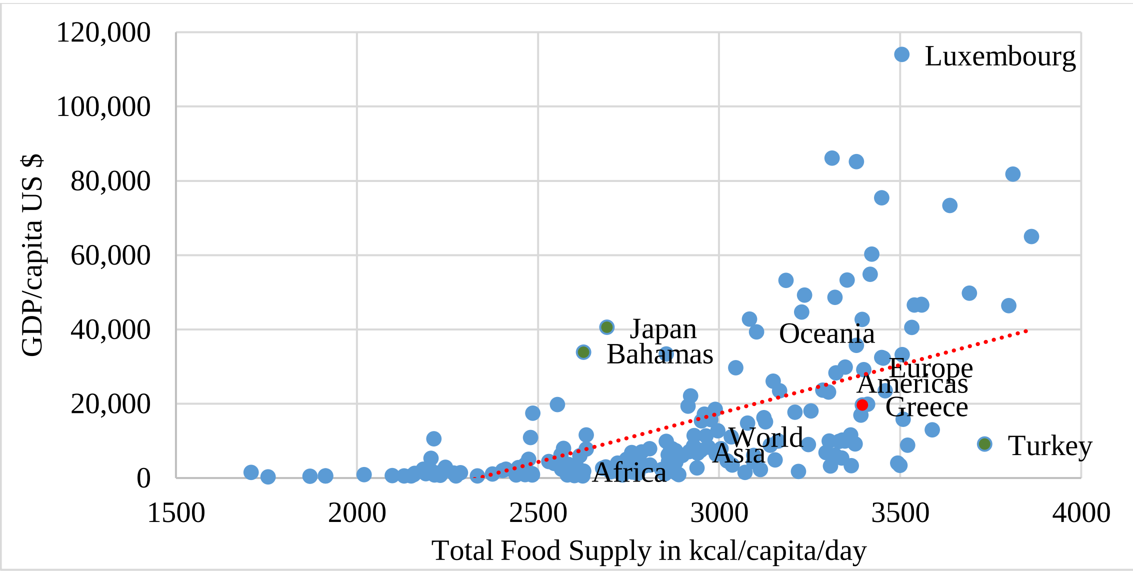
The increase in total food supply has as a result the increase in fat supply too. In 2019, total fat supply was 155 g/capita/day, increased by 77,6% since 1961. The greater proportion (62.4%) was from vegetal products, unlike Europe where fat from animal products dominated (53.6%). However, in world and Europe, animal fat as proportion of total fat is reducing while in Greece it is following an upward trend (see, Graph 1.1). Fat supply translates to 35.28% and 38.82% of dietary energy intake in 1990 and 2013, respectively (OWID, 2021).

Graph 1.1: Total fat supply (gr/capita/day) and animal fat supply as % of total fat supply, 1961-2019



Source: FAOSTAT (FAO, 2021, 2022a)
Note: Data have been estimated with the new methodology since 2010.

Graph 1.2: Total food supply (kcal/capita/day) and GDP/capita (US $) for 179 countries and 6 regions, 2019



Source: FAOSTAT (FAO, 2022a)

Food supply is highly associated with income as in high-income countries food availability is higher than low-income countries (FAO, 2022b). Using per capita gross domestic product (GDP) (in US $)[2] as an income proxy and data from 2019 for 179 countries and 6 regions, this positive relation is clear through the upward red trend line in Graph 1.2. This is also confirmed by using time-series data for Greece, from 1961 to 2019, and GDP per capita in constant 2015 US$ as a proxy for income (see, Graph A.1.3, in Appendix A1). Analyzing this relationship for each food category, it is derived that, in Greece, food availability is positively related with income for all food categories, except for cereals, pulses and fruits for which a negative relationship exists. For total food, meat, milk and cereals, we observe a stronger linear correlation compared to the other food categories. Last but not least, animal fats supply seems to have no correlation with income while the scatter diagram for fruits and fish shows weak correlation (see, Graph A.1.4, in Appendix A1).

1.1.2 Overweight and Obesity

Poor diet along with moderate physical activity are the behavioural and environmental facts which lead to increased BMI. These factors play vital role in the energy balance, as they might increase the energy intake or decrease the energy expenditure (Hill, 2006; WHO, 2022a).

Due to environmental changes, the availability of cheaper foods with higher energy-dense and less nutritionally benefits has increased (WHO, 2022a). Moreover, with the modern pace of life, people are missing many hours from home and do not have free time. As a result, people change their food habits by substituting homemade food with food eaten out. This may lead to excess calorie intake and increases the risk of obesity, because of the large portion sizes and the increased energy density of foods.

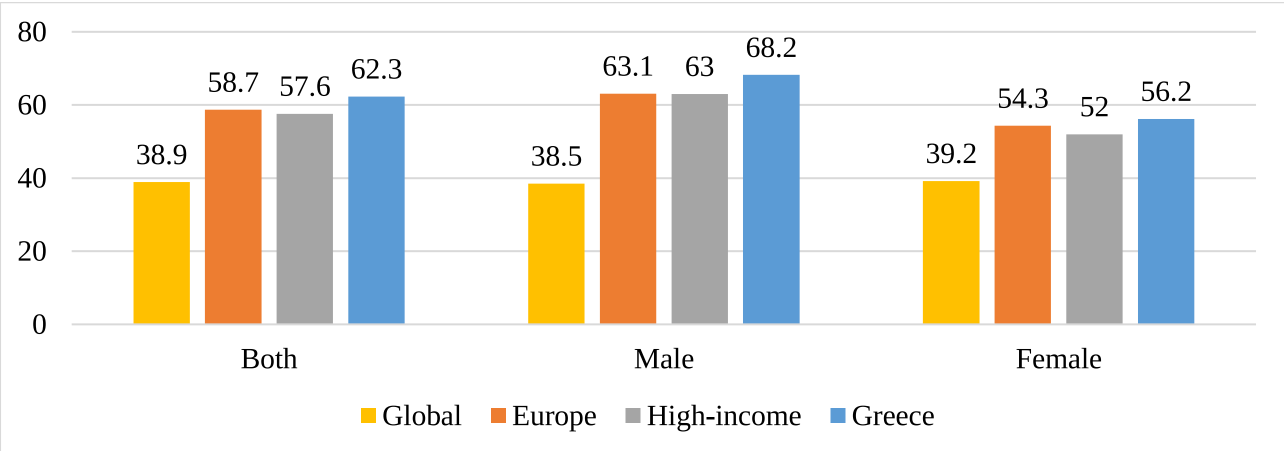
On the other hand, in modern society, there are multiple factors which lead to a significant decrease in physical activity in an everyday framework. Some of them are the replacement of the manual work with sedentary types of work, the technological progress which has led to the extensive use of machinery and appliances, and the use of transports (Maffeis, 2000; Martínez-González et al., 1999; WHO Consultation on Obesity, 2000). Additionally, people in their free-time choose mainly activities with low energy expenditure, such as watching TV or playing on the computer (Friedman, 2000).

[2] Because we have a country comparison, it is more preferable to use per capita GDP in PPP $. Per capita GDP in US $ is used in order to also include the six regions highlighted in Graph 1.2. However, independently of the income proxy, there is a positive relationship between income and food supply (see, Graph A.1.2, in Appendix A1).

Obesity is also caused by genetic factors. If we exclude the cases of people suffering from rare syndromes associated with the weight gain, there are genes that their existence indicates a greater propensity to store the excess food intake in the form of fat (Spiegelman and Flier, 2001). According to studies in families and twins, genes have a strong influence on a person's weight, as approximately 50% of the variation of body weight is due to genetic hereditary factors (Lyon and Hirschhorn, 2005). That means that someone's chances of being overweight are greater if one or both of his/her parents are overweight or obese (Lifshitz, 2008). However, these genes exhibit a tendency to weight gain only when they are in the appropriate environment such as eating patterns with excess calories and a sedentary lifestyle (Comuzzie and Allison, 1998; Hill and Peters, 1998). Families share food and physical activity habits, and that is something which gives a link between genes and the environment (CDC, 2022).

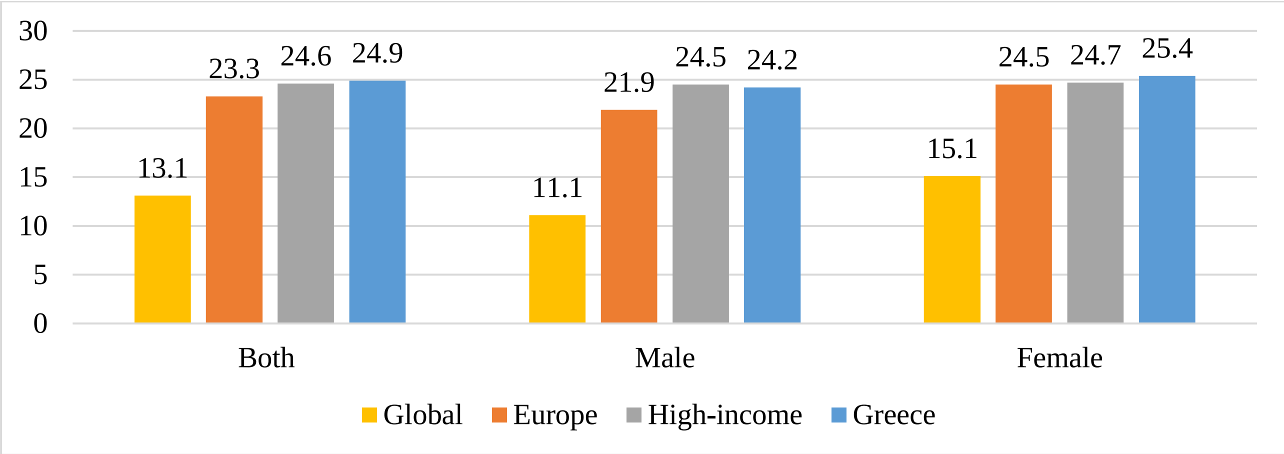
Evidence shows that overweight and obesity are following an upward trend for both adults and children, with worldwide obesity being about triple for adults and more than eightfold for children and adolescents aged 5-19 years since 1975 (see, Graphs A.1.5 – A.1.6, in Appendix A1). In 2016, among the 27 EU countries, Greece was ranked first and third in terms of childhood and adult overweight (BMI≥25) rates, respectively. Among adult population, 24.9% (24.2% for males; 25.4% for females) were obese (BMI≥30) and 62.3% (68.2% for males; 56.2% for females) overweight. The mean BMI was 27.1 (27.5 for males; 26.7 for females), which means that, on average, Greek adults are overweight (see, Graphs 1.3 – 1.5).

Graph 1.3: Age-standardized prevalence of overweight (BMI≥25) among adults, 2016 estimates



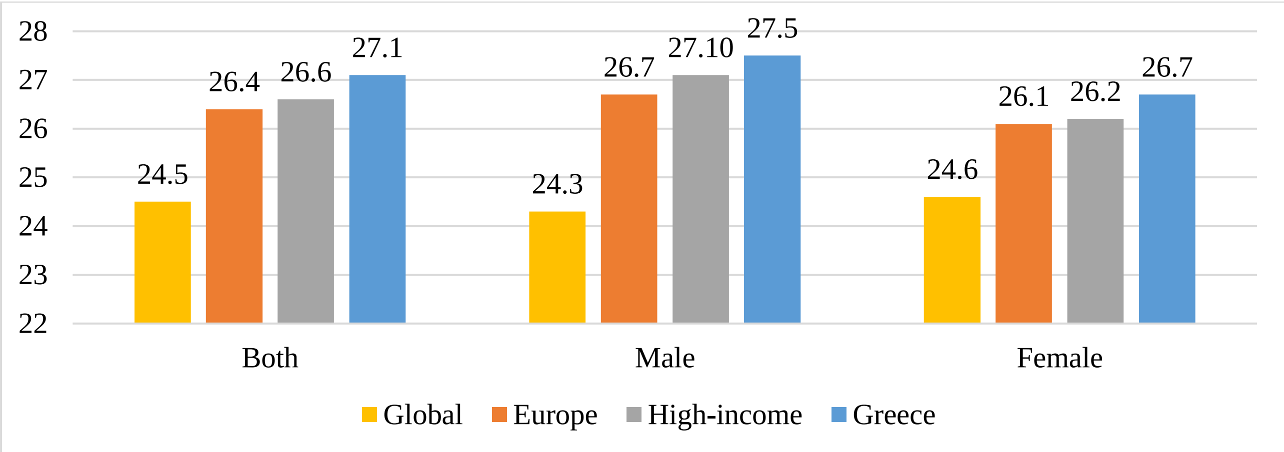
Source: Global Health Observatory data repository (WHO, 2017a)

Graph 1.4: Age-standardized prevalence of obesity (BMI≥30) among adults, 2016 estimates



Source: Global Health Observatory data repository (WHO, 2017a)

Graph 1.5: Mean BMI, people aged ≥ 18 years, age-standardized, 2016 estimates

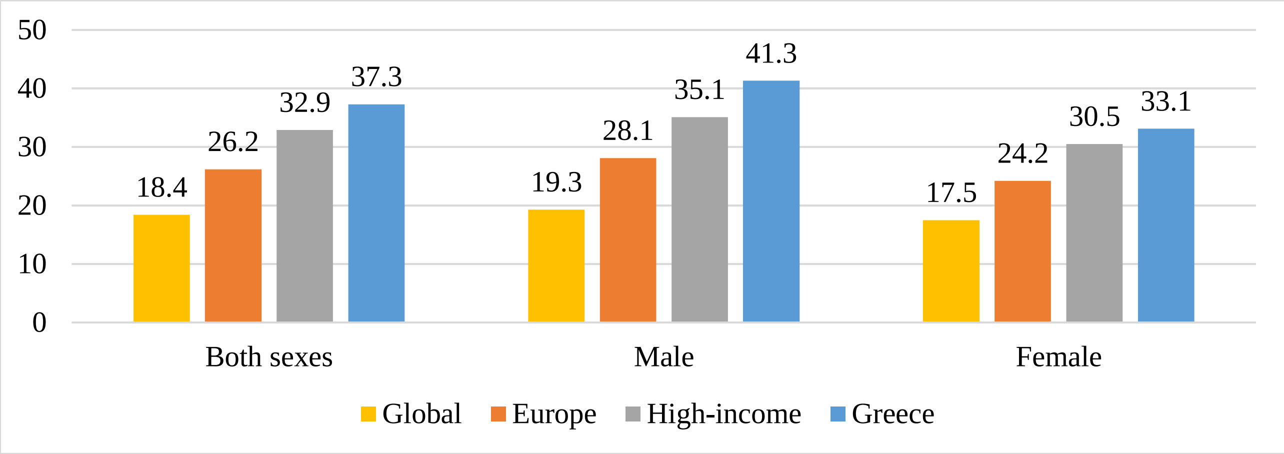


Source: Global Health Observatory data repository (WHO, 2017a)

As regards children and adolescents aged 5 to 19 years, 13.8% (16.8% for males; 10.7% for females) were obese and 37.3% (41.3% for males; 33.1% for females) overweight (see, Graphs 1.6 – 1.7) (WHO, 2017a). Prevalence of overweigh and obesity for both adults and children were much higher than the global average and well above the average for Europe and high-income countries. The only exception was the prevalence of obese adult males and girls which was lower than the average for high-income countries.[3]

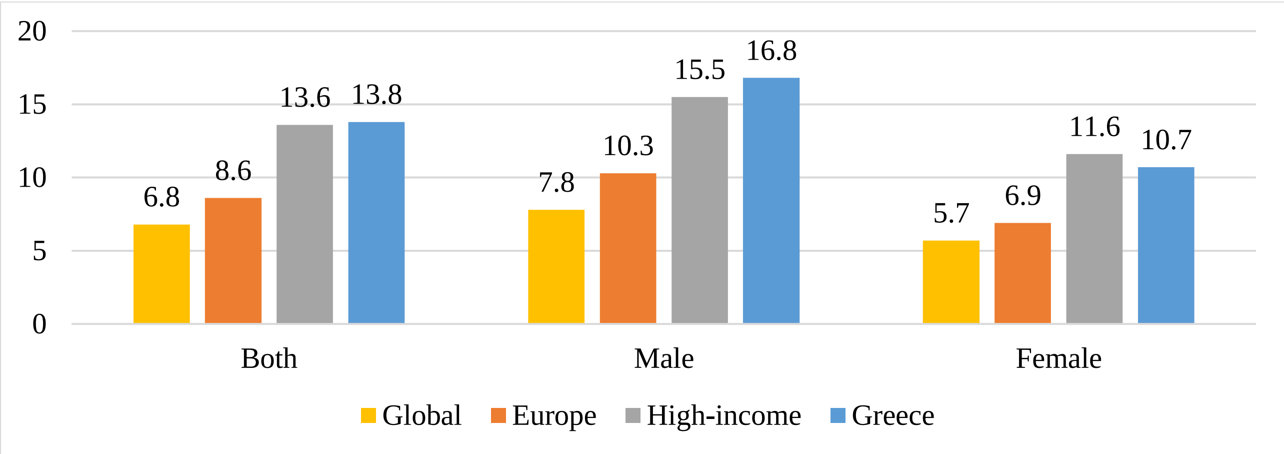
[3] We note that the prevalence of overweight and obesity was age-standardized for adults but crude estimates for children.

Graph 1.6: Prevalence of overweight among children aged 5-19 years, 2016, crude estimates



Source: Global Health Observatory data repository (WHO, 2017a)

Graph 1.7: Prevalence of obesity among children aged 5-19 years, 2016, crude estimates

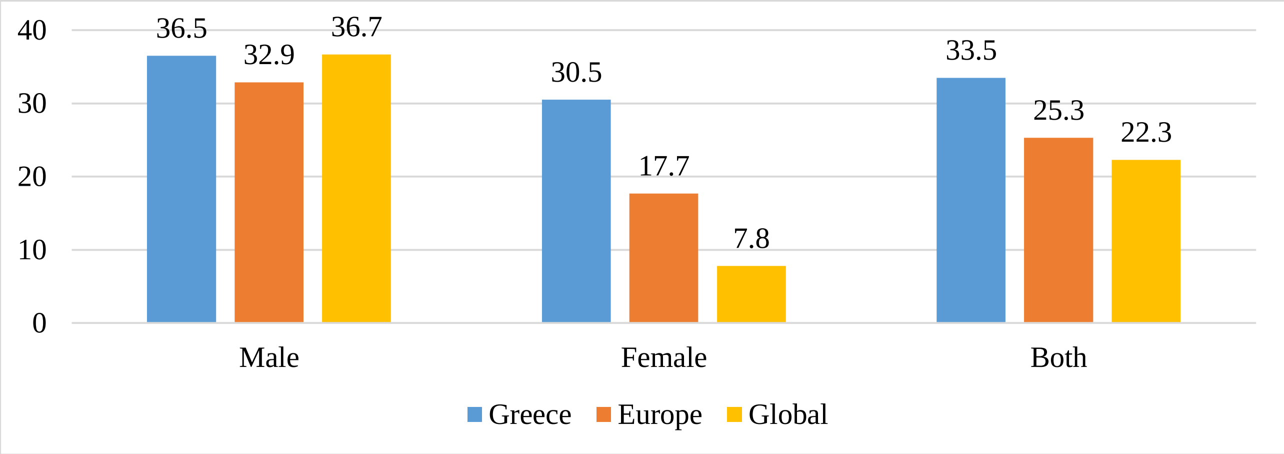


Source: Global Health Observatory data repository (WHO, 2017a)

1.1.3 Tobacco Use

Another concern, for Greece, is the high consumption of tobacco products. Specifically, in 2020, the estimated age-standardized prevalence of current tobacco use, among people aged 15 and above, was 33.5% (36.5% for males; 30.5% for females), a percentage well above the worldwide and regional average. Moreover, estimated prevalence by gender shows that, compared to the global and the European region situation, the difference in tobacco use prevalence is negligible for males but much sharper for females (WHO, 2021a) (see, Graphs 1.8).

Graph 1.8: Age-standardized prevalence of current tobacco use among people aged ≥ 15 years, by gender, 2020 estimates



Source: WHO global report on trends in prevalence of tobacco smoking 2000-2025 (WHO, 2021a)

Tobacco smoking does not harm only the active smokers but also the passive ones who breathe in tobacco smoke. The results of the 2019 European Health Interview Survey show that, in Greece, 28% of people aged 15 and over were exposed daily to tobacco smoke indoors. Greece is fifth among the EU countries, with the EU average being 15.4% (Eurostat, 2022) (see, Graph A.1.7, in Appendix A1).

The proportions of current tobacco users and daily exposure to tobacco smoke might be high but time series data show an important decline in both. In 2000, the prevalence of current tobacco use was 54.9% and, with a continuous decreasing trend, it is expected to reach 29.8% by 2025 (WHO, 2021a). On the other hand, in 2014, Greece was Europe's capital of second-hand smoke with 64.2% of people aged 15 and over being exposed daily to tobacco smoke indoors (Eurostat, 2022) (see, Graphs A.1.7 – A.1.8, in Appendix A1). The reduction of both active and passive smoking is the result of the implementation of combined policies against tobacco as introduced by WHO with the WHO FCTC (WHO, 2022b).

1.2 The Consequences of Unhealthy Eating, Overweight/Obesity and Tobacco Use: Health and Financial Problems

1.2.1 Health Problems

Unhealthy eating, obesity and tobacco use are among the major risk factors for our health as they are linked with a number of chronic diseases. Specifically, unhealthy eating increases the risk of cardiovascular diseases, cancer, diabetes, osteoporosis, dental diseases as well as of obesity (WHO and FAO Expert Consultation, 2003). On the other hand, both tobacco use and obesity increase the risk of developing various chronic diseases, such as cardiovascular diseases, respiratory diseases, cancer, type 2 diabetes and musculoskeletal disorders (CDC, 2020, 2019). The link between musculoskeletal disorders and obesity is obvious as the excess weight strains bones and joints. However, there is also a number of studies relating musculoskeletal disorders to smoking (e.g., Bedno et al., 2017; Hurley and Winstanley, 2015; Palmer et al., 2003). The most known negative effects of smoking are the loss of bone mineral content and increased incidence of fractures (Abate et al., 2013). Back pain may also be related to smoking (Green et al., 2016). According to Abate et al. (2013), "the most widely accepted explanations for the association between smoking and disc degeneration include an adverse toxic activity of nicotine itself, increased degradation of collagen, and decreased blood and oxygen supply, resulting from the vascular damage, and/or vasoconstriction of the vascular network surrounding the intervertebral discs". Tobacco smoking and obesity also increase the risk of developing digestive (e.g. gallbladder disease) (CDC, 2020; Li et al., 2014), neurological (e.g. Alzheimer's disease) (Durazzo et al., 2014; Profenno et al., 2010) and eye diseases (e.g. cataract) (Pan and Lin, 2014; Zhang et al., 2011).

Tobacco smoking could also cause injuries (Leistikow et al., 1998; Sacks and Nelson, 1994; Wen et al., 2005). According to an overview study (Sacks and Nelson, 1994), a variety of reasons might explain this association, including direct toxicity (e.g., increases in driving judgment errors and reduced driving performance), distractibility (e.g., holding a cigarette might lead to temporary attention loss), smoking-associated medical conditions (e.g., smoking-related diseases might affect recovering from an injury or increase the risk of an injury) and confounding factors (e.g., alcohol or drug use and depression), including personality or behavioural characteristics.

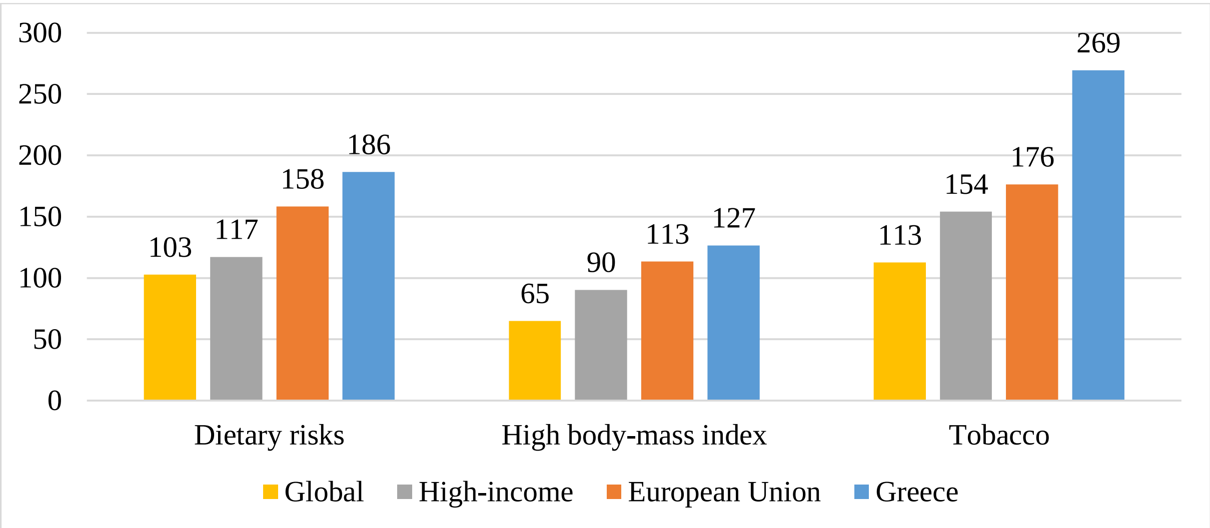
On the other hand, obesity is also linked with physiological problems. In western societies where the lean body is identified with happiness and social acceptance, if someone does not have the ideal body, they are leaded to social discrimination and prejudice (Hafner et al., 1987). Obese people are treated as less attractive and they often deal with social isolation and racism (Puhl and Heuer, 2010; Stunkard et al., 1986). At the same time, they feel great anxiety because of their image and they are often observed to develop disorders of dietary intake (Allon, 1979).

Generally, risk factors might lead to disability and premature death. A recent comprehensive review of 57 international prospective studies found that moderate obesity (BMI 30-35 kg/m2) reduces life expectancy by an average of three years, while morbid obesity (BMI 40-50 kg/ kg/m2) reduces life expectancy by 8-10 years. Interestingly, the years of life lost due to morbid obesity is equivalent to the effects of lifelong smoking (Prospective Studies Collaboration, 2009).

Based on the 2019 GBD study (Global Burden of Disease Collaborative Network, 2020), 62.74% of deaths and 26.86% of YLDs in Greece were attributable to GBD risk factors. Among the twenty risk factors (level 2), tobacco[4] is a leading one, ranging first in deaths and second in YLDs with a rate of 269.31 and 1,270.09 per 100,000, respectively. Dietary risks[5] and high BMI are also high in the list with the former being more severe regarding deaths and the latter causing more YLDs. Specifically, dietary risks is the second most severe behavioural risk factor with 186.4 deaths (third in the rank) and 392.64 YLDs (fifth in the rank) per 100,000. As regards high body-mass index,[6] it is ranked third in YLD with a rate of 908.15 and sixth in death rate (126.53 per 100,000). It is also worth noticing that alcohol, which is a well-known sin good, and physical activity, which is a determinant of obesity, are lower in the rank (see, Graph A.2.1, in Appendix A2).

As shown in Graphs 1.9 – 1.10, death and YLD rates attributable to tobacco are higher than the corresponding rates for the European Union and high-income countries and more than double the world's rate. As regards high-body mass index and dietary risks, the death rate is still higher but closer to the comparable regions. On the other hand, YLD rate is higher than the world's rate and lower but close to the rates for the European Union and high-income countries.

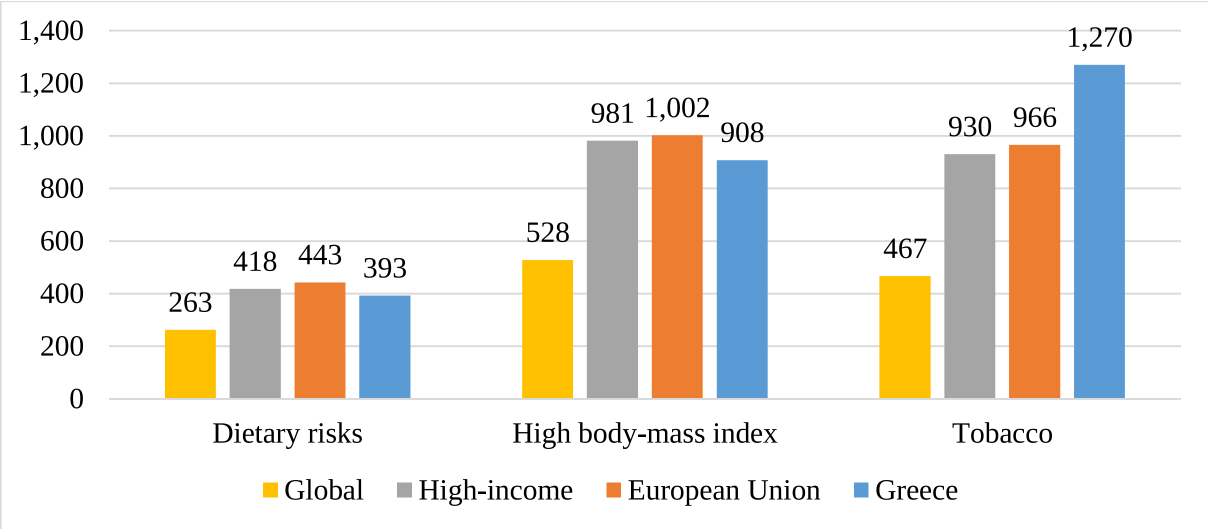
Graph 1.9: Deaths attributable to dietary risks, high-body mass index and tobacco, rate per 100,000, 2019



Source: 2019 GBD study (Global Burden of Disease Collaborative Network, 2020)

[4] Tobacco includes active and passive smoking as well as chewing tobacco.
[5] Dietary risks include diets low in fruits, vegetables, whole grains, nuts and seeds, fiber, milk, calcium, omega-3 oils, and polyunsaturated fatty acids; and high in sodium, red meat, processed meat, sweetened beverages, and trans fats.
[6] High body-mass index refers to both overweight and obesity.

Graph 1.10: YLDs attributable to dietary risks, high-body mass index and tobacco, rate per 100,000, 2019



Source: 2019 GBD study (Global Burden of Disease Collaborative Network, 2020)

Nowadays, tobacco might be the most serious risk factor but data over time have established high BMI and dietary risks as a major health threat. During the period 1990 - 2019, YLD rates have increased greatly for both high BMI (by 75%) and dietary risks (by 77%), while for tobacco they increased by a lower rate (46%). For all three risk factors, the increase was higher in the last decade compared to the previous two decades. As regards the other regions of our interest, they follow the same upward trend on YLD rates related to high BMI and dietary risks but tobacco-related YLD rates are almost stable (see, Graphs A.2.2 – A.2.4, in Appendix A2).

As regards death rates, during the period 1990-2010, these were more stable for dietary risks than obesity but both have increased more sharply during the last decade. Tobacco-related death rates follow the same pattern as those related to dietary risks. The comparable regions have also an upward, but slower, trend on death rates related to high BMI. On the other hand, contrary to Greece, they present downward trends on death rates related to dietary risks and tobacco, which are sharper in the first two decades (1990-2010). In each year, the world's death and YLD rates are lower than the corresponding rates for high-income countries, the European Union and Greece (see, Graphs A.2.2 – A.2.4, in Appendix A2).

1.2.2 Financial Problems

Health problems related to risk factors, such as tobacco and obesity, have serious economic consequences. First of all, they are associated with healthcare expenditures, which create a burden not only to individuals themselves (throw private healthcare spending) but also to society as, in Greece, about 60% of total healthcare expenditure is public (OECD, 2020a).[7] Diseases related to risk factors create also indirect costs because of morbidity and premature mortality. These costs are measured as the productivity lost by persons who are ill and unable to work (morbidity cost) or have died prematurely (mortality cost).

The total global economic cost of smoking is estimated to be 1.8% of global GDP (Goodchild et al., 2018). For high-income countries, the estimated direct costs of smoking account for between 0.1% and 1% of GDP while direct and indirect costs range from 0.3% to 2% of GDP (Vulovic, 2019). Similar is the impact of obesity, with the economic cost ranging from 0.45% to 2.4% of GDP (OECD, 2019; Okunogbe et al., 2021). For the OECD countries, the economic cost of obesity is estimated to reduce GPD by 3.3% (OECD, 2019). This thesis is contributing to this field, by estimating the economic cost of all three risk factors of our concern (i.e., dietary risks, high BMI and tobacco – both smoking and SHS).

1.3 Ways of Tackling Obesity and Tobacco

The previous Sections of this Chapter highlighted the heavy burden that tobacco use, unhealthy diet and obesity impose on society. This evidence underlines the need for efficient interventions to combat the tobacco and dietary/obesity epidemic. The tobacco problem was observed many decades ago and progress on policy implementations has already been made. On the other hand, dietary problems and obesity are more recent problems and there is significant room for improvement on prevention policies. The current tobacco and dietary/obesity policies are presented in Sections 1.3.1 and 1.3.2 of this Chapter, reporting also the policies adopted in Greece.

1.3.1 Tobacco Control Policies

Measures which can be implemented against tobacco epidemic are reported in the WHO Framework Convention on Tobacco Control (FCTC) (WHO FCTC, 2003). The WHO FCTC includes measures that reduce both demand and supply of tobacco products. Most measures aim at the demand side (articles 6-14: price and tax measures as well as non-price measures to reduce tobacco demand) and others at the supply side (Articles 15-17). The WHO FCTC contains also provisions for research and surveillance programmes and reporting, exchange of information and scientific and technical co-

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[7] These health expenditures are from all causes and not only from obesity-related diseases.

operation (articles 20-22). Some of these measures, and the extent they are implemented in Greece, are reported below.

1.3.1.1 Measures Aiming at the Demand Side

- **Protection from Exposure to Tobacco Smoke (Article 8)**

Smoking has negative consequences for health, not only for smokers but also for those exposed to tobacco smoke. The implementation of a smoke-free law, which bans smoking in public places, is the most-implemented article of FCTC (WHO FCTC, 2018). Several countries (parties to FCTC) have extended the banning to outdoor areas such as parks (e.g., Luxembourg, Malaysia, Singapore) or playgrounds (e.g., Luxembourg, Sweden). In Greece, conventional smoking in public places is banned since 2009 (law 3730/2008 (A' 262)) and extended for e-cigarettes in 2017 (paragraphs 1 and 2 of article 24 of law 4419/2016). However, there was low -almost zero-compliance of smoke-free law especially in cafes, bars and restaurants. The actual implementation of this measure took place after a decade, in 2019. Smoking in public places has been significantly reduced, however, there are still some cases of non-compliance mainly in bars. Additionally, smoking is banned in private cars when minors under 12 years are present since 2018 (circular 8809.31-01-2018 (Greek Ministry of Health, 2018)).

To ensure the compliance and enforcement of smoke-free law, government should implement a sufficient level of inspection and enforce severe and swift penalties to both smokers and place owners who do not comply with the law. This will also satisfy people who, in the vast majority, are disappointed with the smoke-free law violation (KAPA Research, 2017, 2013). Funds from fines could be dedicated to increase the number of staff involved in National Tobacco Control Programme, as the current number of full-time equivalent staff is only one (WHO, 2021b), and/or to finance actions for this policy or other tobacco control policies.

- **Packaging and Labelling (Article 11)**

Many smokers might be aware of risks of tobacco use but they tend to underestimate them. For that reason, in 2016, Greece adopted the directive 2014/40/EU (European Parliament & Council of EU, 2014), introducing pack warning labels. These labels are strong, graphic warnings about the dangers of tobacco use and cover 65% of front and back side of pack. However, this measure would be more effective if it was combined with plain packaging (also called standardized packaging), as health warnings become more noticeable and make tobacco products less appealing. The first country worldwide to have adopted plain packaging was Australia (in 2012) while for the EU was Romania (in 2016). In total, seventeen countries had adopted the plain packaging legislation by 2020 (WHO, 2021b).

Also, it is important to mention that tobacco industry has already introduced new e-cigarettes which look like lipstick or USB drive, making them popular among youths as it is more difficult to be identified. Thus, it is vital to introduce a law for plain and easily recognizable devices in order to protect minors.

- **Education, Communications, Training and Public Awareness (Article 12)**

Using all available communication tools, Greece should strengthen public awareness of tobacco control issues. Greeks believe that information is the most effective measure (KAPA Research, 2017, 2013), however, in recent years, there is no national campaign related to tobacco (WHO, 2021b). Government should invest in educational and public awareness programmes at annual basis in order to inform public and specially minors about the negative consequences of tobacco use. These campaigns could also inform smokers about the benefits of the cessation of tobacco use and tobacco-free lifestyles. In order to be effective, however, campaigns must target specific population groups, taking into account age, gender and socioeconomic differences as well as the educational background. Additionally, for the effective and appropriate implementation of each tobacco control policy, all related parties should be trained appropriately.

- **Tobacco Advertising, Promotion and Sponsorship (Article 13)**

Advertisement is an industry marketing tactic to promote their products. In order to reduce tobacco consumption, bans to all kinds of direct and indirect tobacco advertising should be enforced. In Greece, the forms of tobacco advertising which are already banned are those through media (television, radio, internet and print publications) and sponsorships. With the law 4419/2016, advertising bans were also broadened to new tobacco products and e-cigarettes. However, it is important to extend the ban to other forms of advertisements such as point of sale advertising and promotional discounts. This is really important for e-cigarettes and new tobacco products, as the interest has been shifted to these kind of tobacco products and there is great effort to gain higher market share.

Additionally, it is vital to impose anti-tobacco mass media campaigns, especially on TV during programmes that children watch, acting as a preventive measure. Mass-media campaigns could inform large population groups about the risks of tobacco use and passive smoking, motivate and inform people on how to quit tobacco use and increase public support for control policies.

➢ **Cessation (Article 14)**

A high percentage of smokers who are aware about the risk of tobacco use, want to quit but only few get help and support. In order to treat tobacco dependence, government should implement programmes including primary healthcare services, free telephone help lines (quit lines) and free or low-cost medicines. In Greece, there are many free primary healthcare services but the cost for medication is not covered (WHO, 2021b). Additionally, there is the telephone help line 1142 which, however, is not free. National Health System should compensate for comprehensive smoking cessation therapies to strengthen the effectiveness of other TC measures.

➢ **Price and Tax Measures (Article 6)**

Greece is one of the countries with the highest tax on tobacco products, accounting for 80.84% of retail price of the most common brand[8] (excise tax is 61.48% and VAT is 19.35%) in 2020 (WHO, 2021b). Taxation generates revenues which can be used to implement other tobacco control policies. However, globally, only 0.4%[9] of these revenues goes to tobacco control efforts (WHO, 2017b). As it is known, the combination of different policies could have better results in the reduction of smoking prevalence and prevention of starting smoking. Thus, it is crucial that the government uses a larger part of tax revenues to implement the policies mentioned above.

1.3.1.2 Measures Aiming at the Supply Side

➢ **Illicit Trade (Article 15)**

In Greece, the constant increase in cigarettes price in combination with the economic crisis had as a result the continuous decrease in tobacco sales. This decrease, however, does not reflect the actual reduction in consumption as many smokers turned to cheaper products through private imports of duty-free products or illicit trade. Hence, tobacco control policies could not have had the desirable effects on tobacco consumption and government lost revenues. At present, Greece permits a limited quantity per traveller but it should make the law stricter and ban duty-free sales, as part of them ends up in illicit trade.

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[8] The most common brand is a premium one (Marlboro). The proportion is even higher for mid-priced and economy brands.
[9] Worldwide, revenues from tobacco excise taxes are more than US$ 250 billion but governments spend only around US$ 1 billion on tobacco control.

As regards illicit trade, data on cigarettes sales show that, in 2017, it counts about one fourth of actual consumption[10], a share which is about 89% higher than the corresponding in 2012 (Euromonitor International, 2018), underlining the need for immediate interventions. Thus, in order to compact illicit trade, Greece implemented the law 4410/2016, according to directive 2014/40/EU. Based on that, a record was established in the Customs Information System (ICISnet) for registering, keeping and monitoring all licenses granted to natural or legal persons operating within the supply chain of tobacco and manufactured tobacco. Additionally, any kind of cross-border distance sales was banned, such as internet sales, as products may not comply with the EU directive and it is easier for young people to get access to tobacco products.

In 2017, the Greek Operational Coordination Centre (OCC) was established, which combats the smuggling of products subject to excise duties. OCC coordinates the Services involved in prosecution and use available information to optimize the effectiveness of controls (OCC, 2019). In the same year, the Greek tobacco products company "Papastratos" donated the first self-propelled control system (X-ray) which can scan up to 80 trucks/containers per hour. At the same time, other three of them were bought and twelve were in the final phase of procedures in order to be included in the Public Investment Program (Capital.gr, 2017). These systems are to be placed in customs with increased risk of tobacco smuggling.

A promising policy is the implementation of a Tobacco Traceability System on tobacco which are manufactured in the Union or imported into the Union. All unit packets of tobacco products are marked with a unique identifier, containing detailed information from production (e.g. the date and place of manufacturing, the machine used to manufacture the tobacco products etc.) to final consumer (the intended market of retail sale).This system has already been applied to cigarettes and roll-your-own tobacco by May 2019 and it should be extended to other tobacco products by May 2024 based on directive 2014/40/EU.

A successful implementation of policies against illicit trade requires reliability and honesty of all parties. However, this is not consistent with Greece's profile as it is a country with high corruption (Transparency International, 2022). Therefore, in order to tackle illegal tobacco trade, government should also tackle corruption. These policies are new and we should wait in order to draw conclusions about their effectiveness.

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[10] Actual consumption is the sum of legal sales and illegal trade.

1.3.2 Dietary and Obesity Control Policies

In order to combat and prevent obesity, policy makers follow a two-side strategy. On the one hand, they target policies which support healthy diet, influencing demand, access and affordability for foods and drinks high in sugar, salt, saturated fats and trans fats. On the other hand, they introduce policies aimed at increasing regular physical activity. Particular focus is given to children, for whom small improvements in health could lead to great effects on morbidity and mortality. The needed actions to support healthy diet and regular physical activity are reported in the "WHO Global Strategy on Diet, Physical Activity and Health" (WHO, 2004), adopted in 2004, while a recent report is specialized on WHO European Union (WHO, 2022a).

1.3.2.1 Policies on Healthy Diet

Starting with policies related to healthy diet, these focus both on the consumer and market environment side. As regards the consumer side, the recommended policy is the implementation of national or targeted information campaigns. The aim is to inform consumers about the health benefits induced by more balanced diets (Capacci et al., 2012; Réquillart and Soler, 2014). This constitutes by far the most common type of policy to promote healthy eating with the most widespread action being aimed at increasing fruit and vegetable consumption, generally based on the “5 portions a day” message (Capacci et al., 2012). Unfortunately, there is no strong evidence about policy effectiveness in terms of changing nutritional intake or health markers like body mass, blood cholesterol, or blood pressure (Capacci et al., 2012; Réquillart and Soler, 2014).

This has led governments to enact policies focused on the market environment side. Such policy is changes in the food supply to facilitate healthier choices for consumers. In order to achieve that, there is a direct approach through which governments are implementing partnerships with the food industry and the retail sector to generate changes in the supply side. These changes may be the insert of new healthier products or the improvement of the existing products. Although these changes seem ideal, they exhibit some problems. The main one is that consumers believe that the more unhealthy the product, the better taste it has (the so-called ‘unhealthy = tasty’ intuition), which lead them not to prefer the healthier products. Thus, a single firm has no interest in deviating from the equilibrium by enhancing the healthiness of its products as it is very hazardous for its sales. To be effective, voluntary agreements should be based on industry commitments rather than individual firm commitments. However, coordination costs are often high, and voluntary agreements on collective standards might be difficult to implement, particularly in fragmented industries (Réquillart and Soler, 2014).

These difficulties in voluntary changes made health agencies envisage minimum quality standards (MQS) as another direct approach to increase the nutritional quality of the food supply (Réquillart and Soler, 2014). In Europe, Denmark was the first country implementing mandatory standard on nutrient content of foods other than those regulated by food safety laws. The Danish ban, which was introduced in January 2004, is imposed on artificial trans fats and restricts the use of industrially produced trans fatty acids to a maximum of 2% (Capacci et al., 2012). This ban was expanded to all European Union countries in April 2019 according to the Regulation (EU) 2019/649 (European Commission, 2019).This approach seems to be effective for some specific nutrients (e.g., salt in bread, added sugars in soft drinks). Nevertheless, MQS might be difficult in practice, especially when it involves numerous nutrients (Réquillart and Soler, 2014).

Except for direct approaches, there are also indirect approaches such as labeling, advertising regulations and taxation. Starting with labeling, it is a policy which reduces consumers' information costs and increases market transparency (as regards the nutritional attributes). Also, it affects the price and quality of firms' decisions and contributes to product reformulation and innovation (Réquillart and Soler, 2014).

In most countries, back-of-pack nutrition declarations are mandatory and are based on global guidance[11] by the Codex Alimentarius Commission[12] (Obesity Evidence Hub, 2020; WHO, 2004). Now, clear front-of-pack nutrition labelling is recommended to become mandatory (Obesity Evidence Hub, 2020), as it could lead to products' reformulation to healthier variants, increasing the impact to society (WHO, 2022a). A map with countries implementing front-of-pack labelling is presented in Graph A.3.1, in Appendix A.3.[13]

These changes in products may seem beneficial, but they are not costless, as reformulation and innovation increase producer's cost which is passed on to consumers in the form of higher food prices (Golan et al., 2001). From the vast literature on consumer responses to labeling, it appears that the overall impact of descriptive labeling remains modest. In particular, it depends on the socio-economic status of individuals, with less-educated individuals responding less to the information (Réquillart and Soler, 2014).

[11] For the global guidance, see Codex Alimentarius Commission (1985a, 1985b)
[12] The Codex Alimentarius Commission is the international food standards agency.
[13] Source: The Global Food Research Program (2022).

As regards the advertising, many reports worldwide show that most of advertisements are related to food and beverages with low nutritional quality, especially during children' programmes. That has a causal, albeit modest, impact on children' food choices and food intake. Thus, a first goal is the ban of 'unhealthy' products' advertising during programmes for which children form a large proportion of the audience (Réquillart and Soler, 2014). More broadly, marketing ban should be enforced in all media, including the media of modern age such as digital and social media (WHO, 2022a; WHO Regional Office for Europe, 2016). An example of generic advertising control is a French law which stipulates that each food advertisement must be accompanied by a public health message. Unfortunately, in European countries, existing evaluations of advertising controls reveal some weakness in their approach (Capacci et al., 2012). While, outside Europe, Kent et al. (2011) examined the nutritional quality of foods advertised to children in Ontario, where advertising is self-regulated by the industry, and in Quebec, where a child-directed advertising ban exists. Their results show that advertised foods in Quebec are marginally healthier than those in Ontario. To be effective, advertising bans should be well designed, which means to encompass a sufficiently wide range of products and affect a sufficiently wide range of audience (Réquillart and Soler, 2014). A map with countries restricting marketing food to children is presented in Graph A.3.2, in Appendix A.3.[14]

Last but not least, the implementation of fiscal policies is recommended. These policies include taxes on unhealthy goods (those high in fats, sugar and salt) and subsidies on healthy goods (e.g., fruits and vegetables) (WHO, 2004; WHO et al., 2017). The aim is to change the relative prices of healthy and unhealthy foods or nutrients (Capacci et al., 2012) and thus their affordability.

There are three types of sin tax. The first one is a tax which applies to food categories but it is difficult to define tax policies leading to an improvement in the intake of all nutrients. A second way is taxing the worse products within a product category. This taxation is sensible as products within a category are highly substitutable. The key in this type of tax is the definition of a quality threshold which will allow substitution, within the product category, between taxed and untaxed products. Moreover, this tax may lead firms to adjust the contents of their products in order to avoid it. The third way is a nutrient-based tax which can be defined more efficiently (in comparison with the food-based tax) (Réquillart and Soler, 2014). However, this type of tax is more complicated and costly to implement (Leicester and Windmeijer, 2004a). It is recommended that countries should implement a tax on sugar-sweetened beverages (SSB) and consider a tax on high-fat and high-sugar foods (WHO et al., 2017).

[14] Source: The Global Food Research Program (2022).

Also, combining taxes with subsidies might be an even more effective measure (Thow et al., 2014; WHO, 2015). A map with countries implementing SSB taxes is presented in Graph A.3.3, in Appendix A.3.[15]

1.3.2.2 Policies on Physical activity

Apart from policies targeting the eating habits, there are also policies with the focus on physical activity. Such policies are provided by the WHO "Global action plan on physical activity 2018–2030: more active people for a healthier world" (WHO, 2018a). A common policy is communication campaigns. The goal is to inform about and raise awareness of health benefits and the social, economic, and environmental co-benefits of physical activity. It also highlights the need for access to quality public places and spaces with adequate infrastructure to support walking and cycling. These places should provide road safety, ensuring the safety of people who are physically active such as cyclists. Other policies enhance the introduction of more physical activity programmes, in natural environments, as well as in sports facilities, workplaces, community centres etc. These programmes should be provided for the whole population. Additional physical activity programmes should be promoted for special groups such as older people and the least active groups (WHO, 2018, 2004).

1.3.2.3 Policies Targeting Childhood Obesity

Special attention is given to children, for whom recommendations to address obesity are presented analytically in the WHO report on Ending Childhood Obesity (WHO, 2016a). On top of the policies on healthy eating and physical activity for the general population, policy makers have also included further recommendations for children. Specifically, to enhance healthy food intake, it is recommended for schools, child-care settings and recreation facilities to create healthy food environments, implementing mandatory national food standards, such as limiting the availability of unhealthy foods. In Greece, a 2013 legislation determinates food offered in school canteens[16] while a nutrition circular in Kindergartens[17] is followed since 2020 (GINA WHO, 2022; Global Obesity Observatory, 2022).

A complementary policy to above gives emphasis to equal access to healthy food for all children. It is proposed to provide free meals in the aforementioned settings to children in disadvantaged

[15] Source: The Global Food Research Program (2022).
[16] Source in Greek here.
[17] Source in Greek here.

communities, such as those with low-income households. A map with countries implementing policies to improve school food environment is presented in Graph A.3.4, in Appendix A.3.[18] Also, as regards physical activity, good-quality physical education should be provided in all educational institutions. Schools, as well as public spaces, should be equipped with the appropriate facilities (WHO, 2004, 2016a).

Policies on childhood obesity contribute to children' protection even before their birth. Guidance on appropriate nutrition intake before conception and during pregnancy and monitoring mother's weight gain and possible hyperglycemia and hypertension during pregnancy are recommended. Mothers should also be supported to breastfeed through regulations such as maternity leave (WHO, 2004, 2016a).

1.3.2.4 Obesity Policies Implemented in the WHO European Union

A recent obesity report (WHO, 2022a) presents, briefly, the policy approaches in the WHO European Region. Among policies, awareness campaigns and public education were the most implemented with countries preferring more those for physical activity than diet (94% and 81% of countries, respectively). Also, in most Member States (44), there were national food-based dietary guidelines but only 31 countries had national guidelines on physical activity. A third policy with great implementation is the one related with the marketing of unhealthy foods and beverages, targeting children. In 34 countries (68%), these marketing policies were mandatory while for 17 (32%) were voluntary.

On the other hand, front-of-package labeling and fiscal policies were implemented by a small number of countries. Specifically, about one fourth of countries (14) had mandatory front-of-pack labelling policies and 15% (8) had voluntary policies. As regards fiscal policies, 12 Member States had SSB taxes and only 3 countries had taxes on HFSS[19] foods (6%).

1.3.3 A Key Difference Between Taxation and Other Policies Intended to Combat Unhealthy Behaviours

In this thesis, we focus on taxation as a policy to combat unhealthy behaviours. A key difference between taxation and the other ways of combating, for example, obesity is that it is cost-efficient and

[18] Source: The Global Food Research Program (2022).
[19] High in Fat, Salt and Sugar.

provides revenue for the government. To have the desired result and to take full advantage of the fat tax policy, governments should use the collected revenue in such a way as to help reduce obesity further. They could, for example, fund health-promoting programmes, such as media campaigns, in order to inform the public about the hazards of unhealthy goods and promote a healthier lifestyle, encouraging physical activity and healthier diets; offer healthier meals in schools, providing more fruits and vegetables for children to get used to a balanced and correct diet from an early age and increase physical education; invest in creating biking/hiking paths, inner-city basketball courts, swimming pools and parks (Center for Science in the Public Interest, 2022). Moreover, governments can help low and middle-income people, providing better health services or coupons for healthier food.

On the other hand, government could use this revenue for purposes other than the fight against obesity. For instance, it could incorporate revenue into the general budget and use as needed or to reduce debt. Doing so, however, it might lose public support for the imposition of the fat tax, as it is then seen simply as another revenue raising device.

Chapter 2: Studies on Fat Tax and its Applications

Fat taxes have already been implemented in some countries with the most of them introduced on sugar-sweetened beverages. At the same time, there is a great number of studies examining the effects of fat taxes and/or thin subsidies on food consumption as well as on other outcomes such as calories intake, body weight, body mass index, obesity and obesity related diseases. Of particular interest are control trials, experimental studies and opinion surveys related to fat taxes. Control trials give the effects of a fat tax using data from a period when the tax was in act for a while. On the other hand, opinion surveys picture public opinion about these taxes and, together with the experiments, give a picture of how people might react to price changes.

The countries which have already implemented a fat tax as well as studies about fat taxes are reported below.

2.1 Countries Which Have Introduced Fat Taxes

Worldwide, many countries have already introduced a fat tax on unhealthy foods with the most taxed product being SSB. Specifically, at least 54 countries have implemented taxes on SSB. From them, 29 countries have specific tax (based on volume or sugar content), 13 countries have ad valorem tax (as a percentage of the wholesale or retail price), and 2 countries have a mix of the two types. Also, 13 countries apply a tiered excise tax, depending on sugar content (Obesity Evidence Hub, 2020).

In Europe, the countries with a SSB tax are Belgium, Finland, France, Hungary, Ireland, Latvia, Norway, Spain, Poland, Portugal and the United Kingdom. Denmark, Finland and Norway were among the first countries worldwide which had implemented SSB taxes in the 1920s-1930s but for revenue purposes (The World Bank Group, 2020). For health purposes, the first SSB tax was introduced in 2011 in Finland and Hungary. The rest EU countries applied the tax after 2016 with Poland and Spain being the most recent ones (January 2021).[20] All but Spain have a specific tax, while Ireland, Latvia, Portugal, as well as the United Kingdom, apply also tiers based on sugar content. Spain did not introduce an excise tax but increased the value-added tax to 21% (from 10%). Finland, Latvia

[20] A timeline is presented in Graph A.3.5, in Appendix A.3.

and the United Kingdom have taxed not only sweetened beverages but also unsweetened beverages (Obesity Evidence Hub, 2020; WHO, 2022a).

There are also countries which have implemented fat tax on other sugary foods (e.g., ice cream) or fatty foods (e.g., butter). In January 2010, the Romanian Government announced the possible introduction of a tax that would impact on foods that are high in fats, salt, sugars and additives (Lomas, 2010). Unfortunately, the idea was axed after the government considered its potential impact on consumers, particularly given rising food prices. There were also concerns that the tax might lead low-income Romanians to resort to even cheaper products, potentially worsening their diets (Cheney, 2011).

In 2011, Denmark introduced the first worldwide tax on products with more than 2.3% saturated fats like butter, cheese, pizza, meat, even milk (BBC, 2011), equivalent to €2.15 per kg of these fats (Smed, 2012). Thus, the price of butter and margarine rose by more than 20% and the price of cooking oil by 8.2% (Snowdon, 2013). By implementing this tax, Denmark intended to decrease consumption levels by 4%. But, this tax was abandoned fifteen months later due to claimed unintended consequences. More particularly, it was blamed for helping inflation rise to 4.7% in a year in which real wages fell by 0.8% and it was estimated to have costed 1,300 Danish jobs. Additionally, it had a very limited impact on the consumption of ‘unhealthy’ foods as many Danes switched to cheaper brands or went over the border to Sweden and Germany to do their shopping (Snowdon, 2013).

In 2011, Finland restored its taxes on sweets (candies, chocolate, cocoa-based products, ice cream, ice lollies, etc.) at the rate of € 0.75 per kilogram. This tax had been abolished in 1999 and the decision to bring it back was made in 2009, ostensibly for health reasons (Snowdon, 2013). It is worthwhile to mention that in Finland, which traditionally ranks in the top 10 of ice-cream eaters per capita, in 2013, two years after the tax has been in effect, per capita consumption of ice cream decreased by 20% (Rossi, 2013). Moreover, the existing tax on soft drinks was also increased (from 4.5 cents to 7.5 cents per litre) and its scope was widened to cover further categories of beverages. Following on from the Danish implementation of the first tax on saturated fat, Finland (and Sweden) were considering implementing a similar tax (European Public Health Alliance, 2012). However, the sweet tax was abolished again on 1 January 2017 (Hagenaars et al., 2019).

In 2011, Hungary introduced a tax on a series of unhealthy products: certain soft drinks, energy drinks, pre-packed sweetened products, salty snacks and condiments (European Public Health Alliance, 2012). In 2013, the fat tax on high-sugar energy drinks was 250 forints per litre (€0.80), on soft drinks 200 forints per litre (€0.65), on snacks 250 forints per kilo (€0.80) and on canned marmalade 500 forints per kilo (€1.6).This tax was effective, at least from the revenue side, as the money raised totaled more than €178 million since its introduction and was intended to fund the national healthcare system that has been strongly affected by the economic crisis (Daily News Hungary, 2014).

In 2014, Mexico became the first country in Latin America to implement an excise tax on high-calorie packaged foods, including potato chips, peanut butter and sweetened breakfast cereals, and an increase in the tax on soft drinks (Cornelsen et al., 2015). The tax is 8% for nonessential foods with energy density ≥275 kcal/100 g and one peso per liter for sugar-sweetened beverages (Batis et al., 2016). On the other hand, in 2016, Kerala was the first state in India to introduce a 14.5% tax on junk foods sold in branded restaurants (Krishnamoorthy et al., 2020).

In 2018, Norway increased the tax on sugar products and chocolate by 16.73 NOK per kg, from 20.19 NOK (€2.09) to 36.92 NOK (€3.82) per kg. It also increased the tax on non-alcoholic beverages from 3.34 NOK (€0.35) to 4.75 NOK (€0.49) per liter, which is equivalent to a 40% rise (Øvrebø et al., 2020).

2.2 Studies about SSB Taxes

One of the goods which has extensively been examined for fat tax implementation is sugar sweetened beverages (SSB) as they contain many calories without having nutrients and many studies have shown that their consumption is directly related to weight gain. Most studies have shown that these taxes reduce the consumption of taxed products and the caloric intake which leads to a weight loss and reduction of obese and overweight people. However, these results vary according to the hypotheses made as well as the data and the models used.

2.2.1 Vat Increases

One way for taxing unhealthy foods is to increase the rate of VAT on those products. Based on this taxation policy, Gustavsen (2005) estimated the effects of three different scenarios about a change in value added tax (VAT) and production tax in Norway which, at the time, was 12% and NOK 1.55 per liter, respectively. Specifically, in the first scenario, he calculated the effects of doubling of the VAT (an estimated price increase of 10.8%), in the second scenario he calculated the impact of doubling the production tax as well as doubling the VAT (a price increase of 27.3%) and, in the last scenario, he assumed that Norwegian soda prices decrease down to the Swedish level which was about 21.7% lower. Using data from the household expenditure surveys of Statistics Norway over the 1989–1999 period, he estimated quantile and censored quantile regressions (using Stone's logarithmic demand function) capturing the probable different effects for low-consumption households at the lower tail compared to persons with high consumption at the upper tail. His results indicate that, if the objective is to reduce consumption among the heavy soda consumers, price changes seem to be an effective tool as, in all scenarios, the percentage change in soda consumption is largest in the upper quantiles. Furthermore, if we examine the changes in liters, the effectiveness of those price increases is even larger in the upper quantiles. Comparing now the scenarios, the second one seems to be more effective than the first one as the reduction in soda consumption is higher for all the quantiles. More specifically, doubling of production tax and the VAT will reduce the consumption of the top 5% of soda consumers by approximately 44%, or 74 liters per year, while this reduction is 17%, or 29 liters, when there is only a doubling of the VAT. For the lowest soda consumers, the reduction in their consumption is 17%, or about two liters per year (in the second scenario).

Gustavsen and Rickertsen (2011) estimated the effects of a VAT increase on sugar-sweetened carbonated soft drinks (SSCSD) from 13% to 25% (which is equivalent to an estimated price increase of 10.6%), using data from the household expenditure surveys of Statistics Norway over the 1989–2001 period, and calculated own-price elasticities with quantile and censored (tobit model) regressions. Their results indicate, as those of Gustavsen (2005), that quantity effects are largest among heavy drinkers. However, as regards the percentage effects, their results differ from those of Gustavsen (2005), as the largest effects were found among light and moderate drinkers. More specifically, the VAT increase leads to a reduction in the purchases of SSCSD of 5.1 litres for light drinkers, 6.8 to 11.5 litres for moderate drinkers, and 13.9 to 19.2 litres for heavy drinkers (25%, 15%, and 10% purchases reduction among light, moderate, and heavy drinkers, respectively). That would lead to an annual reduction from 0.3 kilogram for light drinkers to 1.0 kilogram for heavy drinkers. Taking into account only moderate and heavy drinkers, their annual body weight reduction is more than half a kilogram, which translates to more than five kilograms of body weight over a ten year period.

2.2.2 The 20% Tax On SSB

Most studies estimate the effects of a 20% tax on SSB. In the USA, most of the studies were conducted using data from Nielsen Homescan Panels and the National Health and Nutrition Examination Survey (NHANES). For instance, Smith et al. (2010), using an AIDS model and taking into account substitutions with other beverages, found that a 20% price increase on caloric sweetened beverages is estimated to cause an average reduction of 37 calories per day for adults and an average of 43 calories per day for children. Additionally, using the static rule[21] of 3500-calorie per pound of body weight, which is the most commonly used, they found that this reduction in calories leads to a weight loss of 1.72 kilos over a year for adults and 2.04 kilos over a year for children. That has as a result an estimated decline in adult overweight prevalence (66.9% to 62.4%) and obesity prevalence (33.4% to 30.4%), as well as the child at-risk-for-overweight prevalence (32.3% to 27.0%) and the obesity prevalence (16.6% to 13.7%).

Lin and Smith (2010) used the same data and models with Smith et al. (2010), with the only exception that they estimated different elasticities for low and high-income households and, on average, found similar results. More specifically, their results show that a 20% price increase on SSBs would result in a net decrease in calorie intake from all beverages of 34.2 calories a day for all adults (36.8 for low-income adults and 33.3 for high-income adults) and 40 for all children (33.1 for low-income children and 44.7 for high-income children). This calorie reduction leads to a weight loss of 3.6 pounds for all adults (3.8 for low-income and 3.5 for high-income) and 4.2 pounds for all children (3.5 for low-income and 4.7 for high-income). These weight losses decrease the proportion of overweight and obese adults (from 66.9% to 62.8% and from 33.5% to 30.8%, respectively) as well as the proportion of overweight and obese children (from 32% to 26.7% and from 16.1% to 13.4%, respectively). This reduction in overweight and obesity prevalence is predicted to be similar between high- and low-income adults but larger for high-income children than for their low-income counterparts.

Lin et al. (2011) using the same AIDS model, estimated an average daily reduction of 34–47 calories among adults and 40–51 calories among children. However, as regards the weight loss, they went one step further and, except for the unrealistic static rule, they also used the dynamic calorie-to-weight model which assumes that the percentage of weight lost coming from body fat increases nonlinearly with body fat. Their results show that the dynamic model predicts a weight reduction of 0.97 kg in year one (63% of the static model), and the rate of reduction quickly declines, leveling off by year five at about 1.8 kg. This difference between the models is also observed in the calculation of overweight and obesity's reduction. More specifically, the static model predicts a 4.1% drop in overweight prevalence after one year of taxation, whereas the dynamic model predicts a 2.6% decrease.

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[21] The 3500-calorie per pound rule is derived by assuming that weight loss is composed of a fixed mixture of body fat and protein- and water-rich lean tissue. Every pound of fat lost contains about 4300 calories and each pound of lean tissue lost contains about 800 calories (Hall, 2008). The 3500-calorie per pound rule therefore corresponds to an assumption that the composition of weight loss is fixed at about 75% fat and 25% lean tissue.

Finkelstein et al. (2013), taking into account potential substitutions/complementarity between SSBs and twelve food categories, in addition to other beverages, and accounting for endogeneity and censoring (account for zero consumption), estimated a smaller change in caloric intake. More particularly, they found that a 20% price increase would result in a decrease in store-bought energy of 24.3 kcal per day per person, which would translate into an average weight loss of 0.72 kilos during the first year and a cumulated weight loss of 1.31 kilos in the long run. Additionally, they estimated the change in fat and sodium. As regards fat, given that SSBs generally contain none, the direct incremental effect of the tax is negligible but there is a slight indirect reduction of roughly 30 cg (with the highest reduction coming from salty snacks and ice cream). On the contrary, it seems that there is a reduction in consumption of sodium from regular sodas, fruit drinks, diet sodas, candy and ice cream but the increase from canned soups is sufficient to cancel out all the modest decreases in sodium purchases and results in a net increase of 3.4 mg per day.

Going outside the borders of the USA, there are also other studies which examine the impact of a 20% tax on SSBs. Starting with Manyema et al. (2014), compared to the previous studies, their results show a high reduction in obesity with a relatively low energy reduction. More specifically, using own-price and cross-price elasticities derived from systematic reviews and metanalysis studies, they found that a 20% tax in South Africa is predicted to reduce energy intake by about 30 Kj (7,17 kcal) per person per day, with the largest and most significant reductions being in the younger age-groups while obesity is projected to reduce by 3.8% in males and 2.4% in females. On the other hand, Briggs et al. (2013), using contemporary UK specific data, found lower obesity and overweight reductions, 1.3% and 0.9%, respectively, derived from a 15% reduction in sugar sweetened drinks. However, they estimated an AIDS model and a modified approach which allows for differences between observed purchases and actual demand.

Additionally, in India, Basu et al. (2014) estimated the effect of such a tax on obesity and type 2 diabetes, using a Quadratic AIDS model and assuming a linear rise in SSB consumption of 13% per annum (fitting the secular trend from 1998–2012), and a nonlinear rise predicted by a Bass marketing model used commonly by industry for projecting sales growth. Their results indicate that when a linear rise in SSB consumption is expected, the 20% tax reduces overweight and obesity prevalence by 3.0% and type 2 diabetes incidence by 1.6% among various Indian subpopulations, over the period 2014–2023. However, the impact efficacy of taxation is higher when SSB consumption trends are consistent with industry marketing models as it averts 4.2% of prevalent overweight/obesity and 2.5% of incident type 2 diabetes.

A distinctive study is that of Silva et al. (2013), who calculated own price quantity and quality elasticities (they do not take into account substitution between beverage groups) and simulated the impact of 20% SSB tax rate on quality and quantity demanded (a distinguished methodology by Deaton (1988)). Generally, own price quantity elasticities have a magnitude many times greater than that of own price quality elasticities, which means that, after a price change, households on average adjust their purchased SSB quantity more than their SSB quality. This is confirmed by Silva et al. (2013), as they estimate that a 20% SSB tax is expected to decrease the quantity demanded by 12.4% and the quality demanded by 0.3%. In addition, they used the standard unit value methodology which does not distinguish between quantity and quality responses and they found that, in that case, the quantity demanded of SSB would decrease by 22.9%.

A lower tax rate, only 10%, has been chosen by Briggs et al. (2013) in order to estimate the tax impact in Ireland. Assuming a pass on rate of 90% (based on reports from Ireland and France), this tax rate translates into a 9% price rise. Using an own-price elasticity estimate of −0.9, they found that the tax leads to a mean reduction in energy intake of 2.1 kcal/person/day (770 kcal/year). With the use of a comparative risk assessment model (PRIME model), they translate this energy intake reduction to a decrease in obese adult population by 1.3% (9,900 adults) and overweight or obese population by 0.7% (14,380 adults). However, they do not take into account substitution effects and the modelled tax is based on two categories from the SLAN food frequency questionnaire: “fizzy soft drinks” (not low calorie), and “fruit squash” without having specific categories for energy drinks or fruit juice with added sugar.

Before closing this section, it is useful to mention two more studies. The first one is by Finkelstein et al. (2010), who compared the impact of a 20% tax with that of a 40% tax on carbonated beverages only and on all beverages. In order to do so, they analyzed the Nielsen Homescan panel data by independently estimating a two-part marginal effects model—a logistic model that estimates the probability of positive purchases in a given month and a demand model for the consumption level—for each of their seven beverage groups. Their estimates show that a 20% and 40% tax on carbonated beverages would reduce per capita kilocalories purchases of all beverages by only 4.2 kcal/d and 7.8 kcal/d on average, which led to an annual weight loss of 0.20 and 0.37kg, respectively. On the other hand, the reduction in per capita kilocalories purchases of beverages by a 20% and 40% tax on all beverages would be 7.0 and 12.4kcal/d, respectively, while the weight loss of these taxes would be on average 0.32 and 0.59kg per person per year, respectively (the largest estimated reductions in SSB kilocalories as a result of the tax occur to middle-income households). Considering these results, their main conclusion is that large sales taxes on carbonated beverages might improve weight outcomes, but reductions in weight are roughly 60% greater when the tax is expanded to include all beverages, as it is more difficult for consumers to substitute similar products in their efforts to avoid the price increase.

Finally, Lin et al. (2010) focus only on children and examine two scenarios. In the first scenario, they examine the effects of a 20% price increase on SSB and, in the second, a tax is combined with a 20% subsidy on milk. They predicted that a 20% price increase on SSB would result in a 40 calorie-reduction per day from the eight beverages while, in the second scenario, there is a reduction of 21 calories but also an increase of 40 milligrams of calcium per day. In the case of the 20% tax, this is reflected as a reduction in prevalence of childhood overweight (from 32% to 26.9%) and obesity (from 16.1% to 13.4%) but, in the second scenario. the prevalence of overweight and obesity is predicted to rise by about 2%.

2.2.3 Tax Per Ounce

Another proposed tax is the one which applies on the quantity of SSBs. We discuss three studies which examine the introduction of a penny per ounce tax, using estimated elasticities from previous studies. Wang (2010), assuming a 100% pass through of the tax, estimated the impact of an one cent per ounce tax on all beverages sweetened with caloric sweeteners in New York State, which is equivalent to a 20-25% price increase. Using only the own-price elasticity (not accounting for substitution effects) from a recent systematic review of literature, Wang (2010) translates that price increase into an 18% reduction in SSB consumption, which leads to a per-person reduction of 15-35 kcal/day in calorie intake. Regarding health benefits, the proposed tax is expected to reduce mean body weight of the population by 1-2.5 lbs and prevent 3.5% of new cases of diabetes in males and 3.0% in females.

Wang et al. (2012), based on published estimates of the price elasticity of demand, found that a penny-per-ounce SSB tax would reduce consumption of these beverages by 15% (6–24 %) among adults ages 25–64. Assuming, however, that 40% of the caloric reduction would be offset by increased consumption of other, nontaxed, calorie sources, they found that the net caloric savings would be 9 calories per day. Applying the rule that ten fewer calories per day equals one pound of weight loss, the tax-induced net reduction in calories results in a net reduction of 0.9 pound in mean weight, which in its turn reduces the prevalence of obesity by 1.5 % and new cases of type 2 diabetes by 2.6%. Although small, these percentage reductions would, over the course of ten years, result in 95,000 fewer instances of coronary heart disease, 8,000 fewer strokes, 26,000 fewer premature deaths, and more than $17 billion in savings from medical expenditures averted across the US population.

Last but not least, Mekonnen et al. (2013) also used estimates from a recent systematic review of the price elasticity for SSBs and found that a penny-per-ounce tax would result in a 10%–20% reduction in SSB consumption. Additionally, based on the calculation of 3500 kcal/lb, they estimated the weight loss and they used these estimations in The Cardiovascular (CVD) Policy Model- CA in order to calculate the effects on diabetes and CHD. Taking three different scenarios in which they vary the impact of a reduction in consumption of SSB on BMI, they estimate that a 10–20% reduction in SSB is projected to lower incident cases of diabetes by 12,000 to 23,000 (a 1.8–3.4% reduction) and the number of new cases of CHD by 6,000 to 12,000 (0.5–1.0%) from 2013–2022.

A lower tax is examined by Zhen et al. (2013). Using instrumental variables to control for endogenous prices, they estimated a censored Exact Affine Stone Index incomplete demand system for twenty-three packaged foods and beverages and a numéraire good. Their estimates show that, on average, a half-cent per ounce SSB price increase is predicted to reduce per capita SSB purchases by 113 ounces per quarter (the SSB reduction is larger for low-income households than for high-income households because low-income households reported higher quantities of SSBs). Taking into account the predictions of the preferred demand specification, that almost half of the reduction in SSB calories caused by an increase in SSB prices is compensated for by an increase in calories from other foods, an increase in the price of SSBs of one half-cent per ounce is expected to reduce per capita daily calorie intake by 13.2 kcal for the low-income population and 5.6 kcal for the high-income population. Applying these estimates to the dynamic energy-weight loss model used in Lin et al. (2011) predicts weight reductions of 0.37 and 0.16 kg/person in one year and 0.70 and 0.31 kg/person in ten years for low- and high-income adults, respectively. However, contrary to the calorie decrease, a half-cent per ounce increase in sugar-sweetened beverage prices is predicted to increase sodium and fat intakes as a result of product substitution.

A half-cent per ounce on store-purchased sugar-sweetened beverages was also examined by Zhen et al. (2011). However, this study stands out as they take into account habit formation, allowing for the possibility that consumers might develop habits over services and derive utilities from consumption of service stocks. Estimating a two-part model with the second stage being a dynamic AIDS, they found that the tax has low impact on sugar-sweetened beverage consumption as, in the long run, it is estimated to reduce sugar-sweetened beverage demand between 118 and 135 12-oz cans per year for low-income households and between 110 and 128 12-oz cans per year for high-income households. Additionally, it is estimated to boost milk consumption for both income groups in most cases, but the estimated effects are not statistically significant for low-income households. On the other hand, despite the modest effect on consumption, the tax is expected to generate sizable tax revenue nationally in the long run (about $1.9 billion per year). However, these revenues are 15–20% lower than revenue in the short run because demand of habitual goods is more tax-responsive in the long run than in the short run.

Tiffin et al. (2015) estimated the impact of four different cases of SSB taxation in the UK: a tax of £0.06/litre (1) and £0.02/litre (2), once on regular and diet soft drinks and juice drinks with sweeteners (A) and once on the same beverages without the diet soft drinks (B). More specifically, using a Quadratic AIDS model, adapted to account for censoring and price endogeneity, they estimated that, as a result of taxes in scenario A1, A2, B1 and B2, consumers reduce their consumption of both regular soft drinks and cola, on average, by 6.1%, 2.3%, 4.3% and 1.4%, respectively, which translates into a reduction in energy intake from sugar-sweetened soft drinks of 0.02% (A1), 0.008% (A2), 0.014% (B1) and 0.005% (B2).

2.3 Studies about Tax/Subsidies On Nutrients Or Foods

2.3.1 Studies Which Examine Specific Taxes On Foods/Nutrients

Sugar Sweetened Beverages may be blamed for gain weight but they are not the only food category with high calories. There is a wide range of food products which are high in fat, sugar and salt which should be taxed. For example, Duffey et al. (2010) have estimated two step marginal effect models (for price elasticities) and ordinary least square regression models using directly measured individual-level consumption and health-outcome data from twenty-year Coronary Artery Risk Development in Young Adults (CARDIA) Study. Their results showed that a $1.00 increase in soda price was associated with an average 124 fewer total daily kcal, 2.34 pound lower weight, and a 0.42 lower HOMA-IR score[22] for both away-from-home hamburgers and pizza, although the estimates only reached statistical significance for pizza. However, when this price increase applied for both soda and pizza, the change in total energy intake, body weight and HOMA-IR was greater (-181.49 kcal, -3.66 lbs and -0.45, respectively). Thus, these mechanisms might be effective to steer US adults toward a more healthful diet and help reduce long-term weight gain or insulin levels over time. Nevertheless,

[22] HOMA-IR score is a measure of insulin resistance which was calculated as [fasting glucose (mmol per liter) ×fasting insulin (μU per liter)]/22.5]. Higher scores are indicative of increased insulin sensitivity.

they focused on a small number of food and beverage groups leaving out additional and important substitution and complementary foods and beverages that might occur.

Additionally, Thiele (2010) estimated the results of a 0.5 cents tax per gram of saturated fat. Using German data, he estimated a linear approximated Almost Ideal Demand System (LA/AIDS) for ten food groups, which was corrected for bias (because of zero expenditures), and unit values were estimated taking into account different quality characteristic. His results indicate that German households continue to consume about the same total food amounts but they alter their food composition in the direction recommended by nutritionists, consuming less animal but more plant based foods. According to the authors, this would lead to a reduction in energy intake by 73 and 29 kcal per person per day for low-income and high-income households, respectively. Assuming that 70% of the calculated values are allocated to a reduction in food waste, and the remaining 30% to a reduction in energy intake, the amount of calorie reduction falls to 20.4 kcal on average for all households. Even small, this reduction would lead to a decrease in body weight of approximately one kilo per year. Additionally, with the fat tax implementation, the largest changes among nutrients can be identified for the three fat components and especially for fat and saturated fat while the mean total fat consumption is estimated to fall under the recommended values. However, the changed food demand structure is also connected with a decline of deficient intake nutrients such as vitamin D and calcium. These reductions are not desirable as these nutrients are necessary for the prevalence of osteoporosis and, in the case of Germany, vitamin D is underconsumed and many Germans show insufficient calcium consumption. Thus, due to the fact that a fat tax has both positive and negative health outcomes, the net health effect remains unclear. Moreover, the implementation of a fat tax causes not only health but also welfare effects. Considering welfare losses as a percentage of income, it is shown that low-income consumers bear higher welfare losses than high-income households (1.06% for poorer and 0.23% for richer households), making the fat tax regressive.

Abdus and Cawley (2008) found no significant differences among income groups, when they examined the effects of a 10% tax on fat content. Specifically, they used own- and cross-price elasticities of demand of thirteen categories of foods for three separate income groups estimated by Huang and Lin (2000), and found that the difference between low and high income groups is only 0.15 percentage point with the weight loss being 1.43% for the former and 1.28% for the latter group. Huang and Lin (2000), however, had estimated the shares of different categories of foods in total daily caloric consumption only for the low income group. Abdus and Cawley (2008) assumed that the shares of different categories of foods in total daily caloric consumption are the same for all income groups.

Goldman et al. (2011) examined both the short- term and long-term relationships between food prices of various kinds and body weight. In order to achieve that, they captured prices for twenty-two at home-food items and three fast-food items from the ACCRA Cost of Living data and they created an index for price per calorie. That way, they put more weight on foods that are more calorie-dense than others, with increases in this index interpreted as relative increases in the price of high-calorie foods. Their results indicate that, in the short term, there is a modest effect of price per calorie on BMI (or log BMI) which becomes larger in the long-term, but it is still below the threshold of clinical significance (which is at least 10% change in BMI). More specifically, they estimated that a 10% reduction in price per calorie is associated with a BMI increase of approximately 0.26 units (or 0.77%) within two years and 1.05 units (or 2.5%) within ten years. Additionally, they found that the food price effect does not differ by either baseline BMI status or baseline household wealth. However, despite the low impact on short run, this tax may curb the rate of growth somewhat more over a longer period of time. For example, the average BMI of American adults increased by about 2.7 BMI units in a twenty-year period, from 1980 to 2000. Based on the previous estimates, a 10% increase in the price per calorie would have the potential to roll back 38% of this growth within ten years.

The ineffectiveness of such taxes is suggested in the study of Chouinard et al. (2005), who calculated the effects of a 10% tax on dairy products, estimating the own- and price-elasticities for fourteen dairy products categories with an Almost Ideal Demand System (AIDS) that is linear and quadratic in prices and linear in income (LQ-IDS). Their results indicate that the tax has small effects as it reduces the average fat consumption by only 1.4%, that is, 7.4 fewer grams of fat per week or slightly over one gram per day. Additionally, this tax reduces the annual Short-Run Welfare by $22, with the higher loss occurring in poorer families ($25.69 in comparison with the $20.75 loss for higher incomes families). Dividing this welfare loss with the household's annual income, the tax seems to be regressive as the regulatory burden is 0.35% at an income of $7,500, while it is constantly decreasing as the income increases, reaching 0.016% at an income of $70,000.

Taxing all food products high in energy is, of course, politically unrealistic. Allais et al. (2008) determined which food categories should be taxed to have the highest impact on calory intake. In order to achieve that, they estimated price elasticities using an aggregating AIDS model and then translated them into nutrient elasticities. Analyzing the food's contribution of the twenty-two food categories to energy and the corresponding nutrient elasticities, they concluded that taxes on cheese, butter, sugar fat products, and ready meals (especially for energy) have the most effective impact on households' total energy intake, mainly due to reduction of households' saturated fat intake. Unfortunately, when they simulated the effects of a 10% tax on these food products, they found that they have ambiguous and small effects on households' nutrient intake. This is derived from the fact that nutrient price elasticities are remarkably inelastic and that the price increase of a food to reduce calory and/or fat intakes generally reduces intakes of other nutrients deemed good for health. However, despite the small impact in the short run, the tax might lead to non-negligible changes on body weight in the long run. In that case, the question is whether consumers will be patient enough to appreciate the benefit from long term health effects, given that in some cases it could take more than eight years to reach the long term effects, and that in the short run they consume less without immediate substantial effects on their weight. On the other hand, given that the taxed products are inelastic, fat tax policies could raise substantial revenues for the government. However, government has to deal with the fact that these taxes are regressive, especially when they are introduced to sugar fat products. Therefore, in this case, the results also call into question the effectiveness of tax policies intended to alter nutritional intakes.

The above studies emphasize the importance of certain issues. First, low taxes are not able to reduce the consumption of taxed products. In order to have positive health outcomes these taxes should be set at a higher rate. Second, the categorization of the wide range of foods into food groups should be done very carefully, as the availability of the price elasticity estimates of more detailed categories of foods is likely to give a more accurate estimate of the impact of a fat tax. This conclusion comes from Abdus and Cawley (2008), who estimated the effect of a 10% tax on the percentage of fat using, in one case, own- and cross-price elasticities of demand for thirty-nine food categories and, in another case, the elasticities for seven more broader food categories, both estimated by Huang (1993). Starting with the case of thirty-nine food categories, they found that the effects are small as a 10% fat tax reduces body weight by 0.48% which equals a weigh loss of 0.92 and 0.8 lbs for an average male and female, respectively. This is due to the fact that as a whole, food consumption is relatively inelastic. However, when they took into account the elasticities of the seven broader categories, they found a lower impact on body weight. Moreover, they also estimated the effects of a 10% tax on the calorie content of foods and found that it leads to a 0.86% reduction in body weight. Compared with the 0.48% reduction, the calorie tax seems to be more effective in reducing body weight than a fat tax.

A third issue is that, in the estimation of the effects of a fat tax, one should take into account the substitution not only between food groups but also within the food groups. Miao et al. (2013), contrasting a simplified demand system without within-group substitution to the augmented system with the within-group substitution, found that overlooking the within-group substitution the impact of these taxes on consumption patterns and associated reduction of calorie intake are understated while the effect on welfare loss is overstated.

Another study which focuses on within food group substitution is this of Khan et al. (2016), who chose milk as food category in order to examine if changes in prices could alter the relative prices of healthy and unhealthy products within a category. They took sales and price data for milk for the four major fat content levels: whole (3.5% fat), 2 %, 1% , and skim (less than 0.5% fat), and they found that, when prices are uniform, whole milk has the highest market share (36.4%). But, under non-uniform prices, where the price of milk is decreasing with fat content and 2% milk is on average 14 cents cheaper than whole milk, the market share of whole milk falls to 29.7%. The 2% milk has the highest market share under non-uniform prices. Thus, their main result is that influencing choice through price mechanisms can be achieved with relatively small price differences, with the majority of shifts in demand achieved with premiums of just 5-10%. Additionally, they found that under uniform prices, whole milk share for the lowest income quartile exceeds that for the highest income quartile by 17%. As the whole milk premium over lower-fat alternatives increases, whole milk share for both income groups falls, but the response is stronger for low income consumers. The results provide strong evidence that policies based on price incentives can be particularly useful in shifting the purchases of lower income consumers, who are most vulnerable to obesity. Although these results are encouraging, substitution within milk category may be different from substitution within other product category.

2.3.2 Studies Which Compare Different Tax Scenarios

As mentioned before, taxes/subsidies could be introduced in many ways. The vast majority of studies consider many tax/subsidy scenarios in order to find out which one is the most efficient. There are two main findings. The first one is that a tax on nutrients is more efficient than a tax on foods (Smed et al., (2005), Harding and Lovenheim, 2014). A possible explanation is given by Harding and Lovenheim (2014), who suggest that this occurs because the vast majority of product groups, and of products in general, contains sugar, fat and salt and thus nutrient-based taxes have a much broader base. That has as a result that the taxation of these nutrients does not allow consumers to substitute to other goods that also contain these nutrients. The other main finding is that taxing/subsidising specific nutrient (fat, saturated fat, sugar or fibres) might reduce the consumption of taxed products but increase the consumption of other products. Instead, combining these taxes with subsidies on healthy foods/nutrients leads to better results.

Harding and Lovenheim (2014), to find which tax is more effective, compared the estimated effects of a 20% tax on products and nutrients (soda, sugar sweetened beverages (SSBs), packaged meals, snacks/candy, fat, sugar and salt). Using purchasing data from the Nielsen Homescan Panel, a unique dataset as regards its size and scope, they estimated a structural Quadratic Almost Ideal Demand System (QAIDS) model over fourteen product categories, which are then further partitioned into thirty-three different product-nutrient groups. Their findings indicate that, as regards product taxes, meals and candy/snacks taxes produce much smaller nutritional changes than SSB and soda taxes, at a similar utility cost. However, when those taxes are compared with nutrients taxes, it seems that nutrient-specific taxes, i.e., taxes on fat, sugar and salt, have much larger effects on nutrition than do product-specific taxes, without causing a larger decline in consumer utility. Among the taxed nutrients, sugar is the one which stands out as it leads to modest indirect utility cost and to substantial reductions in the purchased amount of calories, sugar, fat, salt and cholesterol, supporting healthier purchasing behavior.

Miao et al. (2013) grouped the available foods into twenty-five food groups and they allocated all food items within a food group to one of four sub-categories on the basis of the share of calories from fat and added sugars (HH, HL, LH, and LL). Then, they considered two tax scenarios focusing on 'bad calories' from added sugar and then from solid fat. For comparison purposes, they established a calorie reduction as the basis of equivalence between scenarios. The calorie reduction considered is equivalent to a soda tax of one cent per liquid ounce, i.e., 2.19% on the basis of their model. Taking into account within-group substitutions, they found that the added-sugar tax is more efficient than the tax on solid fat. However, the sugar tax raises less revenue and creates higher deadweight loss per dollar raised than the fat tax. This is because smaller sugar tax rates are necessary to abate the targeted nutrients.

Mytton et al. (2007), using empirical data derived from meta-analyses, examined the effects on nutrition, health and expenditure of extending value added tax (VAT) to a wider range of foods in the UK. Specifically, they hypothesized three different tax scenarios in which they extended a 17,5% VAT to the main sources of dietary saturated fats, to all foods classified as less healthy by SSCg3d model[23] and to foods which give the best intake outcome while trying to minimise the additional cost to the consumer. In all tax scenarios, they predicted a fall in fruit and vegetable consumption of approximately 2–4%, as a result of cross-elasticity effects, and a reduction in intake of nutrients such as salt and saturated fats by no more than 5–10%, indicating that altering the national diet by judicious use of VAT seems limited. On the scope of cardiovascular deaths now, the first scenario leads to an increase in deaths related with cardiovascular diseases while the other two scenarios lead to an decrease

[23] It is a model which ranks and categorises foods based on eight nutritional parameters: energy density, saturated fat, iron, calcium, sodium, n-3 polyunsaturated fatty acids, non-milk extrinsic sugar and fruit and vegetable content (Mytton et al., 2007).

in deaths, primarily owing to a substantial reduction in salt intake. The largest reduction in deaths is for the last scenario which could avert up to 3200 cardiovascular deaths in the UK per annum (a 1.7% reduction). Although this percentage change is small, the actual number of lives saved could be substantial because of the high incidence of cardiovascular disease in the UK.

Extending the previous analysis, Nnoaham et al. (2009) estimated the impacts on different income groups of four tax/subsidy scenarios: i) a 17.5% value added tax (VAT) on foods that are the major sources of saturated fat, ii) a 17.5% VAT on foods defined as ‘less healthy’, iii) a 17.5% VAT on ‘less healthy’ foods and a 17.5% subsidy on fruits and vegetable, and iv) a 17.5% VAT on ‘less healthy’ foods and a subsidy on fruits and vegetable equal to the revenue of the tax (about 32.5%). The results show that scenario 2 has the greater reduction in calorie, saturated fat and salt intakes across all income quintiles (in average 2.4%, 3.1% and 1.86%, respectively). Nevertheless, it could contribute to between 35 and 1300 additional deaths from stroke and cancer every year in the UK. This is due to the fact that in scenario 2, like scenario 1, there is a reduction of 1.5% in consumption of fruits and vegetables which is due to the cross elasticities effects. On the contrary, scenario 3 could prevent between 1600 and 2900 deaths from CHD, stroke and cancer each year while scenario 4 could prevent the most deaths (3700–6400). However, very few obesity-related CVD deaths would be prevented in any of the four scenarios.

Gustavsen and Rickertsen (2010) estimated the impact of a VAT increase from 14% to 25% (a price increase of 9.6%) for Carbonated Soft Drinks (CSD), candy, and ice cream, and a removal of the VAT (and a price reduction of 14%) for fresh fruits, vegetables, and fish, retaining the VAT for milk, juices, and meat unchanged. As in the case of a VAT increase on SSBs, they estimated censored quantile regressions (CQRs) in order to predict the different effects on high- and low-purchasing households using Norwegian household data. The results indicate that, for heavy consumers, the VAT increase in unhealthy foods leads to a reduction in CSD, candy and ice cream purchases by 10 liters, 1.6 and 0.9 kilograms per year. On the other hand, the VAT removal from healthy foods leads low consumers to increase the purchases of fruits, vegetables and fish by 0.5, 1.2 and 0.6 kilograms per year, respectively. This results in changes in body weight, especially for heavy consumers. For this group, the decrease in body weight is half a kilogram or more and comes from the reduction in consumption of CSDs and candies. However, this policy burdens public revenue as the revenue gain by the increased VAT on unhealthy foods is less than the revenue loss by the reduction in VAT of healthy foods with the final cost being 1400 millions of NOK, excluding the administrative costs.

Additionally, Smed et al. (2005), focusing on the consumption of saturated fats, fibre and sugar in Denmark, investigated the socio-demographic effects of four different tax or subsidy regulation schemes. They estimated own and cross price elasticities for twenty-three food categories (beverages are not included) using an AIDS model which accounts for dynamics in consumer behavior. Their results indicate that general tax or subsidy instruments cannot solve the problems with regard to nutrition and obesity for all groups of consumers while, if the concern is mostly for the citizens with the strongest energy intake (citizens in the lower socioeconomic classes, in the rural areas and among the younger), the evaluations show that none of the considered instruments have particularly advantageous effects. Additionally, from an overall perspective, a tax on fats reduces the total energy intake as well as fat share (total fats as well as saturated fats) of total energy, but increases sugar energy share for most consumers. This is the case for both a tax on all fats and a tax on saturated fats only. On the other hand, a tax on sugar reduces the share of sugar but increases the shares of different fats, whereas the effects on fat and sugar energy shares of a subsidy on fibres are small or negligible. In order to find a solution to that problem, two years later, Smed et al. (2007) estimated the effects of five more tax scenarios. Specifically, except for the three taxes/subsidies on nutrients (fat, sugar and fibres), they also estimated two taxes/ subsidies on food and three tax scenarios which are combinations of the others. Their results show that it is more effective to target nutrients than foods, with the best scenario being a combination of saturated fat and sugar tax plus fibre subsidy. This scenario has as a result the decrease in sugar and saturated fat consumption by 16% and 8%, respectively, and the increase in fibre consumption by 15%. Moreover, as regards the results by age and socio-demographic groups, it seems that lower income groups had the greater improvements in diet composition (which is in accordance with their initial group target) and, as a result, the largest decreases in expenditure. On the contrary, as regards the results by age groups, the response is similar to the previous study, as it did not have the desirable effect because the greater change in demand did not occur for age groups with the largest initial consumption.

Jensen and Smed (2007), using a dynamic linearized Almost Ideal Demand System, estimated the effects on consumption of fat, saturated fat, sugar and fibres for seven tax and/or subsidy scenarios (two subsidy scenarios, three tax scenarios and two combined scenarios). Their results confirm those of Smed et al. (2007) as regards the effectiveness of those taxes/subsidies: they found that only taxing/subsiding specific nutrient (fat, saturated fat, sugar or fibres) might reduce the consumption of taxed products but increase the consumption of other products. For instance, taxing fat or saturated fat might lead to a reduction in the consumption of fat and cheese but also increase sugar consumption. On the contrary, combinations of tax reductions on fibres or fruits and vegetables on the one hand, and increased taxes on the most unhealthy fats on the other hand (the two combined scenarios) are seen to have desirable effects on the intake of fruit and vegetables, and thus the amount of fibres, while at the same time reducing the intake of fats and sugar. Comparing now those two scenarios, they concluded that the combined scenario, which includes a subsidy on fibres and a tax on fat and sugar, is up to 40% (and for sugar even more than 100%) more effective than the other scenario.

Other studies focus their interest on subsidies and have as an alternative the combination of these subsidies with taxes on unhealthy good/nutrients. For example, Nordström and Thunström (2009) mentioned that "According to the Swedish National Food Administration (SLV) the average female is recommended to increase her intake by a minimum of 56%, and the average man by at least 38%. To translate this into recommendations for grain product consumption, SLV recommends that the average person (a) double their overall intake of bread and breakfast cereals, while (b) ensuring that half of the bread and breakfast cereal consumption is wholesome—high in fiber and low in fat, salt and sugar." Using these recommendations as target, Nordström and Thunström (2009) analyzed the effect of a wider range of policy instruments, including subsidies on wholesome products and fiber density and also revenue-neutral reforms, where these subsidies are funded by taxes on unhealthy goods and nutrients. Starting with a removal of the VAT on wholesome bread and breakfast cereals, they found that it reaches the first recommendation but it has little impact on fiber intake. Thus, they continued by simulating the effect of a 50% subsidy on those products and a SEK 0.046 subsidy per gram of fiber. Both of them increase the fiber intake of the average household by the recommended 38%. However, they lead to an increase in the intake of unhealthy nutrients, as well as kilojoules and to sizable decrease in revenue (-160% and -129%, respectively). For those reasons, they examined the case in which those subsidies are funded by taxes on unhealthy commodities or nutrients (revenue-neutral reforms). In detail, the previous three subsidies are funded by a 34,2% (first case) and 113,8% VAT (second case) on bakery products and ready meals and a tax of SEK 0.074 per gram of fat, SEK 0.325 per gram of saturated fat, SEK 0.063 per gram of sugar, or SEK 0.182 per gram of added sugar(third case), respectively. Their findings show that all the simulated reforms might increase the fiber intake but also result in an increase in some unhealthy nutrients and kilojoules. The reform which jumps out for the greatest positive impact on the dietary quality of the average household is a subsidy of the fiber content (i.e., a subsidy per gram of fiber in each kilogram of grain product), which is founded either by an excise duty on added sugar or on saturated fat. In these cases, the increase in fiber intake might be less than it would be if an unfunded fiber subsidy were imposed, but the funded fiber subsidy reform efficiently reduces the increase in the unhealthy nutrients that results from the unfunded reform.

Nordström and Thunström (2010) took their previous study one step further and analyzed the effect across household types of reforms designed to increase fiber intake from grain consumption. Nevertheless, they examined only the four revenue-neutral policy reforms. According to their result, the highest increase in fiber intake from these reforms occur to households without children (seniors, couples without children, and single females without children) which are those with the highest initial consumption share of fiber-rich products. However, these reforms also lead to high increases in unhealthy nutrients and thus, the net health effects are difficult to be evaluated. On the other hand, households with the lowest initial consumption share of fiber-rich products, which are households with children, are affected positively from these reforms. The increase in fiber intake may be smaller than that of the average household but, at the same time, these households generally experience reductions in the intake of added sugar, and in many cases saturated fat nutrients which these families often overconsume.

Using a simple three-good theoretical model (a high-calorie food, a low-calorie food, and exercise), Schroeter et al. (2008) determined the impact of price and income changes on weight. The weight impact depends on the substitutability or complementarity of high-and low-calorie foods and the effect of changes in high- and low-calorie food consumption on weight. Starting with an increase in the price of the high-calorie food, they support that, when high- and low-calorie foods are complements, the tax leads to a weight reduction while, when they are substitutes, the outcome is not clear. Comparing the efficiency of a high-calorie food tax with this of a low-calorie food subsidy, the tax may lead to a higher weight impact when the two goods are substitutes or weak complements. Additionally, Schroeter et al. (2008) examined the impact of income changes and found that an income increase will lead to a weight gain in the case of normal or luxury goods while the only case it leads to a weight loss is when goods are inferior. Appling price and income data and energy accounting into their theoretical framework, they quantify the weight impact of a 10% high-calorie food tax on food away from home or on caloric soft drinks, and the impact of a 10% low-calorie food subsidy on fruit and vegetables or on diet soft drinks. The results show that a relative efficient intervention is to apply a tax on caloric soft drinks while less weight-decreasing is the subsidy on diet soft drinks. On the other hand, the tax on food away from home, the subsidy on fruit and vegetables and income changes are the least efficient alternatives because these market interventions could actually lead to an increase in body weight.

A unique study is this by Allais et al. (2012), who compared the effects of two popular options of nutritional policy: mandatory front-of-pack labelling and the fat tax. Using French household scanner data on fromages blancs and dessert yogurts, disaggregated at both household and product levels, they modeled consumer preferences for those products in a random utility framework, with a Mixed

Multinomial Logit model (MMNL). This model allows for substitutions between food categories and between products within a same food group and for an outside option. Another characteristic of this study is that they control not only for the (usual) endogeneity of prices but also for the endogeneity of fat-content labels. With the use of this model, they conducted four simulations: front-of-pack fat labels to dessert yogurts and an ad -valorem tax of 10% (5%) on the producer price of full-fat (half-skimmed) products with and without producers' price response. Their results indicate that, ignoring producers' price response, both policies lead to a large fall in fat purchases, around 38%. However, after accounting for producer price response, the fat tax annually reduction of this quantity is -9.1%, whereas the labelling policy leads to a much smaller reduction, -1.5%, because the producers of dessert yogurts would accept to cut their margins to retain customers. As a result of this fall in purchases, annual profit falls too with the reduction being considerably larger under the mandatory labelling policy (-21%) than under the fat tax (-6%). On the other hand, as regards the consumer welfare (when the producer price response is taken into account), it would increase by 53% with mandatory labelling, as a result of the fall in prices, and decrease by 2% with the fat tax. However, these welfare calculations do not take into consideration the long-run benefits of reduced fat intake. Thus, these results suggest that from a health policy perspective, the fat tax dominates the mandatory labelling policy while the opposite holds from consumer policy perspective. Additionally, they outline the difficulty of using market tools to achieve public health objectives, as market forces can defeat any intended policy effect.

2.4 Studies on the Regressivity of Fat Tax

Fat taxes have been accused that they are regressive, i.e., affect relatively more the low-income families, as they pay more as a percentage of their income. Being a sensitive issue, it is included in many studies while for some it is the main research question.

Finkelstein et al. (2010) point out that, although lower-income households purchase more SSBs than higher-income households, because they do so at lower average prices and because they are more price sensitive, their share of the tax is less than that of higher income households. Specifically, for a 40% tax on SSBs, households in the lowest income quartile would pay roughly 20% of the tax, those in the middle income quartiles would each pay roughly 25%, whereas the highest income quartile would pay 30% of the tax. Thus, the tax is not regressive as the tax share increases with income .

On the other hand, Lin and Smith (2010) estimated that for a 20% SSB tax, low-income individuals would pay slightly more tax than high-income individuals ($19.97 versus $18.84). By expressing the SSB tax as a percentage of total food and beverage spending, they concluded that a tax on SSB is more burdensome to the low-income population, although it represents about 1% of their total food and beverage spending. Additionally, Zhen et al. (2013) found that a half-cent per ounce SSB price increase leads to a larger SSB reduction for low-income households than for high-income households. However, the welfare loss for low-income households is about $5 per household per year more than high-income households because low-income households reported higher SSB purchases in Homescan, reinforcing the regressive nature of the SSB tax. In a study that takes into account habit formations, Zhen et al. (2011) found that, in the long run, a low-income household is expected to pay between $1.47 and $1.55 per month in tax while the corresponding amount for a high-income household is between $1.32 and $1.41 per month. This is translated to a tax burden of 0.1% of the annual household income for low-income households compared with about 0.03% for high-income households.

By including weight as an argument to the utility function, Lusk and Schroeter (2012) show that a fat tax can be welfare enhancing, if the amount individuals are willing to pay for a one-pound weight reduction is greater than the ratio of the expenditure on the taxed good to the weight loss produced by the tax. Based on results of Dharmasena and Capps (2012) and Zhen et al. (2011) about the weight loss and the expenditure from a tax on sugary beverages, the 'average' household would have to be willing to pay at least $1493 per pound of body weight lost for a tax on sugary beverages to be welfare enhancing at the individual level. Compared to other studies, this amount is really high and, thus, the sugary beverage tax will not improve welfare within the individual-specific context of their model.

Leaving the studies which focus only on SSB taxes, Zhang et al. (2013) investigated child nutrition risks by considering the relation between general and specific food prices (fast food, fruits and vegetables, beverages) and risk of low (LFS) and very low food security (VLFS) status among low-income American households with children. Their findings suggest that the elimination of subsidies, the imposition of taxes, or the creation of other policies that increase food prices, although they may sometimes yield benefits such as reductions in obesity, are likely to decrease food security. More specifically, higher food prices are generally correlated with greater risk of food insecurity. As regards the specific food prices, they found that higher prices of fruits and vegetables are associated with an increased risk of food insecurity. According to the authors, this should concern policy makers as the consumption of fruits and vegetables is below the recommended amounts. Increases in fast food prices have the same effects. However, this is a special case as fast food may be unhealthy but it is also a low-cost item that some food insecure families may use in times and the low prices for these commodities may promote food security. Last but not least, a particularly interesting finding is that increased beverage prices were estimated to be protective against food insecurity but this requires further investigation.

Leicester and Windmeijer (2004), introducing a 1p/kilogram tax on saturated fat, monounsaturated fat, sodium (obtained from salt) and cholesterol, estimated the expenditure changes by income groups. Specifically, comparing the pre- and post-tax expenditures on food by each household, they estimated the percentage of total income each household would lose through the introduction of the tax. Their results show that expenditure changes do not differ among different income groups, indicating that the tax is regressive as it costs the poor relatively more than the rich. Extensively, under the assumption that there is no behavioural changes, the very poorest 2% would spent about 0.7% of their total income on the 'fat tax', whilst the very richest would pay less than 0.1% of their income, a seven times difference. This regressivity holds, even if the tax is implemented on calories (1p/1000 kcal) but at lower percentage. However, there is a limitation in this study as the data used (National Food Survey (2000)) do not include food prepared outside the home, confectionery (a good likely to attract a significant 'fat tax' as a share of retail value), alcohol or soft drinks.

In the aforementioned study of Nnoaham et al. (2009), the impacts by income groups show that all tax scenarios are regressive while positive health outcomes will not necessarily be greater in lower income groups, as overall effects on health by income group show no clear income group gradients. Nevertheless, the analyses in scenarios 3 and 4 suggest that the likely deaths saved through the taxation-subsidy regimens in those scenarios may be more favourable for the poor than the rich.

From another scope, Madden (2015) showed the regressivity of fat taxes by assessing the impact of indirect tax reforms on poverty. The poverty dominance analysis, using consumption dominance curves, indicates that consumption of most food stuffs is concentrated among lower expenditure households. Thus, a fat/SSB tax would be poverty-increasing for a wide range of poverty indices. However, when these taxes are combined with subsidies, they have a limited or perhaps even beneficial impact upon poverty.

2.5 Control Trials

There are studies which examine the effectiveness of SSB taxation by calculating the impact of real taxes on consumption. These taxes seem to be too small and with low or no impact on obesity. For example, Fletcher et al. (2010b), using state-level sales tax information between 1990 and 2006, analysed the relationship between soft drink taxes in states in the USA, which averaged 3%, and population BMI, and found that that an increase of 1% in the state soft drink tax rate leads to a decrease in BMI of 0.003 points and a decrease in obesity and overweight of 0.01% and 0.02%, respectively. Thus, the behavioral response is small in magnitude, even if a relatively large increase of 18% occurs.

Additionally, there are other studies which focus only on children's reaction when a tax on SSB is imposed. One such example is Powell et al. (2009), who examined the effects of state-level soda taxes (about 3.43% on soda sold in grocery stores and 4.02% on soda sold through vending machines between 1997 and 2006) on adolescent BMI and found no statistically significant associations. The only exception is the effect of vending machine soda tax rates on BMI among teens at risk for overweight which, however, is weak as a 1% increase in the vending machine tax rates is associated with a 0.006 reduction in BMI among adolescents at risk of overweight. Another example of the inefficiency of enacted SSB taxation on adolescent BMI is found in Fletcher et al. (2010a). Using regression analysis and soft drink tax data between 1988 and 2006 (the average rate varies between 4.1% and 5.1%), they found that a 1% increase in the tax rate was associated with nearly 8 fewer kcal from soda consumed, an approximate 6% reduction. However, this reduction is completely offset by the increase in whole milk consumption as it is a substitute for soft drinks. The substitution of soft drinks with other high-calorie beverages, such as whole milk, might have no effect on body weight but there might be broader health benefits by healthier choices like milk.

Other studies focus on the amount of tax which passes on to consumers. For example, Colantuoni and Rojas (2012), using two datasets about grocery and store sales, examined the impact of a 5.5% sales tax on soft drinks imposed by the state of Maine in 1991 and a 5% sales tax on soft drinks levied in Ohio in 2003. Their results show that firms did not react in any systematic way as a consequence of the imposition of the tax and they fully passed through the tax to consumers while there was no impact on consumption in Maine, nor in Ohio. As suggested, this inefficiency might have occurred due to the fact that those taxes are not displayed on the shelf. In this case, the tax can be successful only in raising tax revenue.

Additionally, in January 1st, 2012, a tax of 7,16€/hectoliter on sodas was implemented in France. Berardi et al. (2012) examined the impact of this tax on the price of the three main categories of concerned drinks [(i) sodas (including cola, energy, tonic and other soft drinks), (ii) flavoured waters, and (iii) fruit drinks and ready-to-drink teas]. They collected the prices of 850 different beverage products sold in one or more of the 800 supermarkets from August 2011 to June 2012. Their results indicate that, before the introduction of the tax, the average prices of taxed beverages (except for pure fruit juices and, to a lower extent, flavoured water) were remarkably flat while they started to strongly increase from January. In the first quarter of 2012, between 12% and 15% of prices did not change and 7% to 8% even decreased. However, after six months of the implementation, the tax was fully shifted to soda prices while the pass-through to prices of fruit drinks and flavoured waters was about 85% and 60%, respectively. Additionally, their results point to some significant differences in the pass through across retailing groups, with the two retailing groups with the lowest average pass through being the two biggest players in the retailing trade market. Significant differences in the pass through were also observed across beverage brands with the pass-through being significantly higher for private labels than for other brands as, in a very large majority of cases, retailing groups increased more the price of their own brands than those of others.

Small are the effects of the fat tax, too. An example is the 5,5% fat tax which was enacted in Maine in 1991 and lasted ten years. In that period, the obesity rates increased by 7.3% (Oaks, 2005). Oaks (2005), using the obesity rates of Maine and New Hampshire (a similar state without fat tax) for a fourteen-year time period (four years before the enactment of the snack tax and ten years after the enactment), estimated a regression analysis for the interrupted time series comparison group in order to examine whether the snack tax had any impact on these rates. His results indicate that the snack tax, along with other independent variables, accounts for 93.7% of the variations in obesity rates. However, despite the significancy of the regression model, there were no relationships between independent variables and the dependent variable (obesity rate).Thus, those results could not support the hypothesis that the implementation of a snack tax would lower obesity rates in Maine.

In October 2011, Denmark introduced a new tax of 16 DKK (€2.15) per kg saturated fat in food products with saturated fat more than 2.3 grams per 100 gram. Jensen and Smed (2012), using weekly food purchase data from a large household panel dataset for the period from January 2009 until December 2011, made a first assessment of some of the market effects of the Danish saturated fat tax on the product categories most significantly affected by the new tax: butter, butter-blends, margarine and oils. According to data, the prices of those products increased significantly after the implementation of the tax. Comparing these price effects with the ones expected from their theoretical model, the fat tax seems to have been perfectly transmitted to the consumer prices in supermarkets for all four taxed categories. As regards the tax transition from discount stores, the fax tax for butter blends and vegetable oils was perfectly transmitted too, but prices of butter and margarine increased more than the tax. This higher increase in the prices of butter and margarine in discount stores is a kind of utilization as there occur some shifts in demand from high-end supermarkets towards low-end discount stores with the market share for butter being maintained or even improved for discount stores. Additionally, this price increase in taxed products led to a decrease in their consumption in the range about 10 – 20%. However, the analysis is based on a relatively short period after the introduction of the tax (only three months) and thus these results could not capture the long run effects. On the one hand, hoarding before the tax implementation may have affected purchases in the beginning of the taxation period. On the other hand, in the longer run, larger behavioural adjustments and reductions in fat consumption might occur, both on the demand and the supply side.

2.6 Experimental Studies

An experiment was held in a hospital cafeteria where Block et al. (2010) designed a 5-phase intervention with a sequential timeline. More specifically, they started with a 2-week baseline period during which original prices of all soft drinks and zero-calorie water were posted on the refrigerators selling those items. Then, they increased regular soft drinks prices by $0.45 (35%) with new prices posted on the refrigerators and, in the third phase, there was a washout period during which prices were returned to baseline. In the fourth phase, there was an educational campaign with a poster and informational flyers posted at strategic locations in the cafeteria and, lastly, the fifth phase included a combination of the educational campaign with the price increase of the second phase (each intervention phase lasted four weeks). Their results show that compared with baseline phase, regular soft drink sales declined by 26% when the price was increased and this reduction in sales persisted throughout the study period, with an additional decline of 18% during the combination phase compared with the washout period. Contrary to the price increase policy, education by itself seems to have no effect on reducing regular soft drink consumption as it had no independent effect on sales.

Using a virtual supermarket in Netherland, Waterlander et al. (2014) made another experiment of a tax increase on SSBs (soft drinks, fruit juice, flavored milk and energy drinks) from 6% to 19%. In order to make this experiment, 95 participants were recruited within the University, both among staff and students from whom 49 were facing a 6% tax and the other 46 were facing a 19% tax on SSB. The crude differences between the control and experimental group in purchased quantities within the different beverage categories were analysed using independent t-tests. Two regression models for all outcome measures (beverage and snack categories) were constructed: one accounting for basic confounders (gender, student (yes/no) and shopping budget) and one extended model additionally accounting for realism/feasibility score for the Virtual Supermarket, level of habit strength and price perception score. Their results show that both models revealed a statistically significant effect of the SSB tax on SSB purchases. Moreover, participants in the experimental condition had significant higher odds for purchasing products in the category tea/coffee but this was statistically significant only in the first model. As regards the other beverage and snack categories, they found no statistically significant effects on any of the other beverage categories, including alcoholic drinks and there were no significant differences in purchases in any of the major snack food categories including desserts/puddings, crisps, pastry and candy/chocolate.

Waterlander et al. (2012), using the same virtual super market as in the case of soft drinks, experimented with price decreases on healthy foods (no; 25%; 50%) and price increases on unhealthy foods (5%; 10%; 25%). They created nine different conditions and each participant had to deal with one of them. One of their results was that there were no significant interactions between price increase and discount level for any outcome measure, maybe due to their small sample size, and therefore they presented their result at discount and price increase levels separately. As regards the price decreases on healthy foods, they found that participants with the highest discount (50%) purchased more healthy foods than participants with a lower discount. However, in total, they purchased more items and more calories compared to no discount. On the other hand, price increases of unhealthy foods did not create significant effects. Based on these results, they concluded that the studied pricing strategies do not improve overall diet quality.

Another experiment in a web-based super market was contacted by Nederkoorn et al. (2011), who introduced a 50% tax in products with a caloric value of more than 300 kcal/100 g. The results from this experiment show that the high energy dense (HED) tax diminished the purchase of total calories, reducing the calories purchased from carbohydrates but not those from fat and protein. This reduction is substantial and equally successful in people with high and low BMI and in people with high and low budgets. However, participants tended to replace the high price HED foods with the cheaper HED foods rather than purchasing low energy dense alternatives, something which is boosted by the nature of the tax as it is based on prices, so it leads to a larger price increase for the already more expensive products in absolute terms. Additionally, an important point is that participants did not have budget restrictions as they were asked to spend their usual budget. After they finished their purchases, most people had a considerable amount of money left which means that they had the chance to buy more HED foods, if they wanted.

2.7 Opinion Surveys

A key issue for the success of a tax on SSB is initially the awareness of its usefulness and then its acceptance from the majority of people. In order to capture public opinion, Timpson et al. (2013) asked 125 people in North West of England about a 20% tax on SSB via interviews. The majority of respondents (55.8%) felt that a price increase would not change levels of consumption while, as regards its impact, 49.4% felt that it would have a positive impact reporting that it will improve health (42.7%), reduce obesity (30.7%), or reduce consumption (24%). Moreover, Rivard et al. (2012), who made 592 telephone interviews throughout the USA, asked respondents to consider what they would do if their state began collecting a 20% tax on regular soda and SSB. 37% of respondents said that it would have no impact at all, 20% said that they would switch to untaxed drinks (e.g. diet soda and fruit drinks) and 39% said that they would cut back on their consumption of SSB.

As regards the impact of SSB consumption on health, in Timpson et al. (2013), all of the participants reported that SSBs had a negative impact on health, with the majority describing the impact on dental health while very few participants described the impact of SSBs on obesity. Contrary to those findings about the connection of obesity with SSB consumption, Rivard et al. (2012) found that 91% of the respondents knew that frequent consumption of soft drinks increases the risk of obesity. Additionally, the majority of survey respondents knew that it also increases the risk of diabetes (90%) and dental cavities among children (94%), while fewer respondents knew that obesity is related to diabetes (79 %), heart disease (89%), asthma (36%), hypertension (75%) or cancer (44%).

Regarding the acceptability of such a tax, in Timpson et al. (2013), 51.9% of the survey participants felt that a 20% price increase would be acceptable while 79.8% felt that a price increase would be more acceptable if the monies raised were used for health purposes. On the contrary, Rivard et al. (2012) found that only 36% of respondents supported the implementation of a tax on pre-packaged SSB, with greatest support among those aged 18–24 years, those with BMI <30 kg/m2 and those with higher levels of education.

Barry et al. (2013) reinforce the findings in Rivard et al. (2012), as respondents reported higher agreement with anti-tax than pro-tax arguments. Specifically, higher agreements are for anti-tax arguments like the viewpoint that it does not affect consumption of other unhealthy foods (60%), it is a quick way for politicians to fill budget holes (58%), it is an unacceptable intrusion of government into people’s lives (53,8%) and that it is harmful to the poor (51%). Pro-tax arguments, like that SSBs are the single largest contributor to obesity and that an SSB tax would raise revenue for obesity prevention, have lower agreement levels (49% and 41%, respectively) while the remaining pro-tax arguments have less than 40% agreement. This is equivalent to a tax rate of 4% on sugar in order to reduce its consumption by 5%.

PART B: The Economic Cost of Disease Risk Factors in Greece

Risks factors increase the possibility of developing related health problems, leading to less healthy years of life and premature deaths. Based on evidence presented in Chapter 1, it is clear that unhealthy diet, as well as high body-mass index, are two of the most hazard risk factors in Greece.

The main purpose of this part is to estimate the economic cost of high body-mass index (BMI) and dietary risks[24], as diseases attributed to risk factors create a cost to society due to related healthcare expenditures as well as morbidity and premature mortality. The main analysis concerns the economic costs of the selected risks factors in 2017, the most recent year for which data are available. In order to make a ten- and twenty-year comparison, these costs are estimated also for years 1997 and 2007. Additionally, for a comparative analysis, we estimate the economic cost of tobacco use, separately for active and passive smoking. Tobacco use is also characterized as one of the primary risk factors, but tobacco is a sin good for which prevention policies have already been implemented and lessons can be learned.

Part B is structured as follows: Chapter 3 presents the methodology and the data used to estimate the economic cost of risk factors in Greece as well as a literature review, on the topic, for Greece. Chapter 4 continues with the results of the study on the economic cost of dietary risks and high BMI in Greece for the year 2017, including also a ten- and twenty-year comparison. In Chapter 5, results of the estimated economic cost of tobacco use are presented separately for tobacco smoking and SHS exposure, following the same steps as in Chapter 4. Finally, in Chapter 6, results are discussed and conclusions are made.

[24] Dietary risks include diets low in fruits, vegetables, whole grains, nuts and seeds, fiber, milk, calcium, omega-3 oils, and polyunsaturated fatty acids; and high in sodium, red meat, processed meat, sweetened beverages, and trans fats.

Chapter 3: Methodology and Data

3.1 Methodology

The methodology used is the cost of illness (COI) approach, which was developed by Rice and colleagues (Cooper and Rice, 1976; Rice, 2000, 1967; Rice et al., 1985), and has been used in most of the economic cost of disease/injury studies in the literature. Based on the cost of illness approach, the economic costs of a risk factor are distinguished between direct costs (those for which payments are made) and indirect costs (measuring productivity losses due to morbidity and early mortality). We use the WHO toolkit, which is based on this methodology (WHO, 2011). The toolkit was written for the risk factor “smoking” but it can be used for any risk factor.

3.1.1 The Attributable Fraction due to a Risk Factor (RAF)

In order to estimate the economic cost of a risk factor, we multiply each type of cost (i.e. direct and indirect cost) by the attributable fraction due to that risk factor (i.e. the proportion of cost related to the risk factor). The estimation of RAF requires data by exposure status,[25] which are not available for Greece. To deal with it, we use estimated RAFs by 2017 Global Burden of Disease Study (Global Burden of Disease Collaborative Network, 2018) conducted by IHME. These RAFs are by disease, age and gender. The RAFs used to estimate direct costs are the same with those used for the estimation of mortality costs.

3.1.2 Direct Costs

Direct costs represent the monetary value of goods and services consumed, as a result of illnesses related to the risk factor, and for which a payment is made. Direct costs are distinguished between healthcare costs (that is, those that result from the use of healthcare services such as hospitalizations, physician services, medications etc.) and non-healthcare costs (e.g., transportation to healthcare

[25] For example, the smoking status is former smoker, current smoker and never smoker.

providers, informal care, business expenses to hire and train replacements for sick employees etc.). Due to lack of data, we estimated the direct cost of risk factor r (RHErs) focusing only on healthcare costs, as in most studies, using the following formula:

$$\mathbf{RHE}_{rs} = \mathbf{RAF}_{r} \times \mathbf{THE}_{s}$$

where,

- RAF_r = the attributable fraction due to the risk factor "r" (proportion of healthcare spending attributable to risk factor "r")
- THE_s = total national annual healthcare spending by financing source s.

Healthcare expenditures by financing source are categorized as public health expenditures (general government and social security funds), private health expenditures (private insurance and private payments) and other health expenditures. In this study, this categorization is possible only for the 2017 estimations. Thus, for comparison reasons, we present only public health expenditures and total health expenditures. The types of healthcare services include inpatient care (hospitals and residential long term care facilities), outpatient care and medications and other services.

3.1.3 Indirect Costs

Indirect costs represent the productivity loss due to morbidity or early mortality.[26] The indirect cost was estimated analytically by gender, age and disease, using the human capital approach followed in most studies (WHO, 2011).

The population of our interest is males and females aged 15 to 69. The age of 15 is the minimum legal working age while the age of 69 represents the age of retirement. However, only for SHS and high body-mass index data were available for the whole age range. For active smoking, the lower age is 30 years as the health consequences of smoking appear after some years of exposure. On the other hand, the lower age for dietary risks is 25 years.

[26] In general, an imputed value for lost household production services should also be included, but data are not available.

For the calculation of indirect cost, we take into account all diseases for which deaths/disability related to risk factor were estimated by the Institute of Health Metrics and Evaluation (IHME). These diseases are reported in Table A.4.1 in Appendix A.3.

3.1.3.1 Morbidity cost

Morbidity costs represent the value of lost productivity by persons who are ill or disabled from diseases related to risk factor (WHO, 2011).

The indirect morbidity costs of risk factor "r" (RAIC) for disease i, among population subgroup j, is calculated using the following formula:

$$\mathbf{RAIC_{rij} = RAF_{rij} \times TWLD_{ij} \times ERN_j}$$

where,

- RAF_{rij} = the attributable fraction of indirect morbidity costs due to the risk factor "r", for disease i, among population subgroup j
- $TWLD_{ij}$ = total yearly work-loss days in a country due to disease i, among population subgroup j
- ERN_j = mean daily earnings or salary for population subgroup j.

Due to lack of data on total yearly work-loss days and mean daily earnings, however, we followed the method used by Goodchild et al. (2018), substituting total yearly work-loss days with total years lived with disability (YLD) multiplied by employment to population ratio, and mean daily earnings with GDP per worker.

Then, the indirect morbidity costs due to the risk factor "r" (RAIC), for disease i and among population subgroup j, is calculated as:

$$\mathbf{RAIC_{rij} = RAF_{rij} \times EMP_j \times YLD_{ij} \times PROD}$$

where,

- EMP_j = employment-to-population ratio for population subgroup j
- YLD_{ij} = number of years lost to disability caused by disease i among population subgroup j
- PROD = the amount of GDP per worker, calculated by dividing national GDP by total employment.

3.1.3.2 Mortality cost

Mortality costs represent the value of lost productivity due to lives of working-age persons lost prematurely from diseases related to risk factor. The value of life lost is quantified using the human capital approach, which values life according to loss of foregone market earnings (WHO, 2011).

The indirect mortality costs of risk factor "r" (RAMC) resulting from dying from disease i and among population subgroup j is calculated as:

$$\mathbf{RAMC_{rij}} = \mathbf{RAF_{rij}} \times \sum_{\mathbf{a=MINa}}^{\mathbf{MAXa}} (\mathbf{TDEATH_{ija}} \times \mathbf{PVLE_{ja}})$$

where,

- RAF_{rij} = the attributable fraction of indirect mortality costs due to the risk factor "r", for disease i, among population subgroup j
- $TDEATH_{ija}$ = total number of deaths from disease i for population subgroup j whose age at death is within the 5-year age group "a"
- $PVLE_{ja}$ = total discounted present value of lifetime earnings for population subgroup j whose age at death is within the 5-year age group "a"
- MIN_a = minimum age group
- MAX_a = maximum age group (e.g., age 85+)

The PVLE is calculated as follows:

$$\mathbf{PVLE_{ag}} = \sum_{\mathbf{n=a}}^{\mathbf{MAX}} \left(\mathbf{SURV_{ag}(n)}\right) \times \left[\mathbf{ERN_g(n)} \times \mathbf{EMP_g(n)}\right] \times (\mathbf{1+V})^{\mathbf{n-a}} / (\mathbf{1+r})^{\mathbf{n-a}}$$

where,

- $PVLE_{ag}$ = present discounted value of lifetime earnings for a person of age a and gender g
- $SURV_{ag}(n)$ = the probability that a person of age a and gender g will survive to age n
- a = the age of the person at present (death)
- MAX = maximum age group (e.g., age 69)
- g = gender of the person
- ERNg(n) = mean annual earnings of an employed person of gender g and age n
- EMPg(n) = proportion of population of gender g and age n that are employed
- V = growth rate of labor productivity
- r = discount rate

As with morbidity cost, we substituted mean annual earnings with GDP per worker, due to lack of data. Additionally, we assumed a 1% growth rate of labor productivity, a standard practice followed by many other studies. Our alternative option was to use growth in GDP/capita as a proxy for productivity growth; we chose not to, because of negative GDP/capita growth. Regarding the discount rate, to start with, we assumed non-discounting (r=0%) following the view that human life should not be discounted. However, we also performed a sensitivity analysis assuming a discount rate of 3%, which used to be common practice.

3.2 Data and Data Sources

In this section, we present the data used to estimate the economic cost of high BMI, dietary risks and tobacco. This analysis will be very helpful later, for the interpretation of the results. It is vital for us to know if changes in economic cost are caused by changes in YLDs and/or deaths related to smoking/high BMI/dietary risks or by changes in other parameters such as the GDP or the proportion of population who are employees.

The most recent year for which complete data were found is 2017. We also used data for 2007 and 1997 for a ten-year and twenty-year comparison, respectively. Our primary data source is the 2017 Global Burden of Disease (GBD) Study conducted by IHME (Global Burden of Disease Collaborative Network, 2018). The GBD Study is the most comprehensive worldwide observational epidemiological study to date. It assesses mortality and morbidity from 359 diseases and injuries and 84 risk factors at global, national and regional levels. From this source, we use data on a) attributable fraction due to the risk factor “r” (RAF), b) number of years lost to disability (YLD) and c) number of deaths.

Employment-to-population ratio (EMP) is from OECD (OECD, 2020b) based on EU Labour Force Survey. GDP is from October 2019 World Economic Outlook database presented by International Monetary Fund (IMF, 2019). Number of workers is from Hellenic Statistical Authority (ELSTAT, 2017). Total national annual expenditures are from OECD (OECD, 2020a). Population is from the statistical office of the European Union (Eurostat) (Eurostat, 2020). Life tables are from the World Health Organization (WHO, 2018b).

For comparison reasons among years, costs are reported in constant 2017 euros. IMF presents GDP in constant 2010 €, thus, we had to change the base year using the GDP deflator. As regards total national annual expenditures, we converted them in constant 2017 euros using AIC (Actual Individual Consumption) deflator (OECD SHA TEAM, 2014).

3.2.1 YLD and Deaths Related to High BMI

3.2.1.1 YLD Related to High BMI

To estimate the morbidity cost of high BMI, we use the number of YLDs related to high BMI. The number of YLDs for the population of our interest increased by 19% and 3.5% during the first (1997-2007) and second (2007-2017) decade, respectively. As it is shown in Tables 3.1 – 3.2, in the first decade, the number of YLDs increased for both gender and all age groups. The same also occurs in the second decade with only exception the five (four) youngest age groups for males (females). Comparing now the number of YLDs in 1997 with those in 2017, there is an increase for all age groups but males aged 15-29 years. The increase is higher for males (25.8% versus 20.7%) and for people aged 35-54 (31.6%-37.8% for males and 34.7% - 44.8% for females). In all three years, YLDs were divided almost equally between males and females.

When we want to compare the YLDs among years, it is more appropriate to use the rate of YLDs (per 100,000 population) so as to take into account changes in population. In contrast with the number of YLDs, the rate of YLDs increased for both gender and all age groups (Tables 3.1 – 3.2**.** The percentage of YLD attributable to high BMI (PAFs) also has an increasing trend, as we can see in Tables 3.1 – 3.2. PAFs range from 0.2% (ages 15-19 in 1997) to 10.1% (ages 60-64 in 2017) for males and from 0.1% (ages 15-19 in 1997) to 8.8% (ages 65-69 in 2007 and 2017) for females.

Table 3.1: Number, rate and percentage of YLD related to high BMI, males

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	52	57	46	8.4%	-19.4%	-12.7%
20 to 24	739	817	695	10.5%	-15.0%	-6.0%
25 to 29	1,238	1,528	1,204	23.4%	-21.2%	-2.8%
30 to 34	1,472	1,945	1,852	32.1%	-4.7%	25.8%
35 to 39	1,772	2,397	2,332	35.3%	-2.7%	31.6%
40 to 44	2,032	2,635	2,785	29.7%	5.7%	37.0%
45 to 49	2,510	3,259	3,459	29.8%	6.1%	37.8%
50 to 54	2,987	3,893	4,172	30.3%	7.2%	39.7%
55 to 59	3,617	4,369	4,730	20.8%	8.2%	30.8%
60 to 64	4,370	4,870	5,288	11.4%	8.6%	21.0%
65 to 69	4,506	4,898	5,260	8.7%	7.4%	16.7%
All Ages	33,261	43,387	45,933	30.4%	5.9%	38.1%
15 to 69	25,295	30,668	31,821	21.2%	3.8%	25.8%
Rate						
15 to 19	13	17	17	36.5%	0.3%	36.9%
20 to 24	171	218	238	27.3%	9.1%	38.9%
25 to 29	283	350	379	23.7%	8.4%	34.1%

Table 3.1: Number, rate and percentage of YLD related to high BMI, males (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Rate (continued)						
30 to 34	358	446	477	24.8%	6.8%	33.2%
35 to 39	448	549	574	22.5%	4.7%	28.2%
40 to 44	554	652	681	17.6%	4.6%	23.0%
45 to 49	729	853	884	17.0%	3.6%	21.2%
50 to 54	942	1,120	1,169	18.9%	4.4%	24.1%
55 to 59	1,190	1,372	1,422	15.3%	3.7%	19.6%
60 to 64	1,434	1,694	1,757	18.1%	3.7%	22.6%
65 to 69	1,620	1,886	1,932	16.5%	2.4%	19.3%
All Ages	615	790	878	28.5%	11.1%	42.8%
Percentage						
15 to 19	0.2%	0.3%	0.3%	33.7%	-0.6%	33.0%
20 to 24	2.1%	2.7%	2.9%	26.7%	8.9%	38.0%
25 to 29	3.0%	3.7%	4.0%	23.5%	8.1%	33.5%
30 to 34	3.5%	4.4%	4.7%	23.9%	6.6%	32.0%
35 to 39	4.2%	5.0%	5.3%	20.9%	4.4%	26.3%
40 to 44	4.8%	5.5%	5.8%	15.7%	4.0%	20.4%
45 to 49	5.8%	6.7%	6.9%	15.0%	3.2%	18.7%
50 to 54	6.8%	8.0%	8.3%	16.9%	3.9%	21.5%
55 to 59	7.9%	8.9%	9.1%	13.3%	2.7%	16.3%
60 to 64	8.5%	9.9%	10.1%	15.9%	2.4%	18.7%
65 to 69	8.6%	9.8%	9.9%	14.6%	1.1%	15.9%
All Ages	5.4%	6.5%	6.8%	20.3%	5.3%	26.7%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

Table 3.2: Number, rate and percentage of YLD related to high BMI, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	42	48	42	15.1%	-13.0%	0.1%
20 to 24	644	743	656	15.4%	-11.7%	1.8%
25 to 29	1,167	1,534	1,237	31.4%	-19.4%	6.0%
30 to 34	1,521	1,981	1,934	30.2%	-2.3%	27.2%
35 to 39	1,718	2,325	2,335	35.3%	0.4%	35.9%
40 to 44	1,951	2,539	2,717	30.2%	7.0%	39.3%
45 to 49	2,303	3,035	3,334	31.8%	9.8%	44.8%
50 to 54	2,925	3,575	3,940	22.2%	10.2%	34.7%
55 to 59	3,685	4,193	4,552	13.8%	8.6%	23.5%
60 to 64	4,620	4,731	4,912	2.4%	3.8%	6.3%
65 to 69	5,000	5,179	5,210	3.6%	0.6%	4.2%

Table 3.2: Number, rate and percentage of YLD related to high BMI, females (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number (continued)						
All Ages	36,599	46,657	49,460	27.5%	6.0%	35.1%
15 to 69	25,576	29,883	30,869	16.8%	3.3%	20.7%
Rate						
15 to 19	11	16	16	46.0%	3.7%	51.4%
20 to 24	160	217	240	35.5%	10.9%	50.2%
25 to 29	277	376	408	35.8%	8.6%	47.4%
30 to 34	376	477	509	26.9%	6.7%	35.3%
35 to 39	436	542	581	24.2%	7.2%	33.2%
40 to 44	531	622	669	17.0%	7.7%	25.9%
45 to 49	667	770	829	15.5%	7.6%	24.3%
50 to 54	887	992	1,044	11.8%	5.3%	17.7%
55 to 59	1,122	1,251	1,289	11.5%	3.1%	15.0%
60 to 64	1,360	1,510	1,542	11.1%	2.1%	13.4%
65 to 69	1,590	1,738	1,738	9.3%	0.0%	9.3%
All Ages	665	832	911	25.2%	9.5%	37.1%
Percentage						
15 to 19	0.1%	0.2%	0.2%	44.0%	2.9%	48.2%
20 to 24	1.5%	2.0%	2.2%	33.7%	11.1%	48.5%
25 to 29	2.3%	3.1%	3.3%	34.3%	8.1%	45.2%
30 to 34	2.9%	3.6%	3.9%	24.9%	8.3%	35.3%
35 to 39	3.2%	3.9%	4.2%	22.1%	6.8%	30.4%
40 to 44	3.6%	4.2%	4.5%	16.5%	7.0%	24.6%
45 to 49	4.3%	4.9%	5.3%	14.8%	7.1%	23.0%
50 to 54	5.6%	6.2%	6.5%	10.1%	4.5%	15.0%
55 to 59	6.8%	7.5%	7.6%	9.4%	2.2%	11.8%
60 to 64	7.7%	8.4%	8.5%	9.1%	1.5%	10.7%
65 to 69	8.2%	8.8%	8.8%	8.0%	-0.1%	7.9%
All Ages	4.8%	5.7%	6.1%	18.5%	5.4%	24.9%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.1.2 Deaths Related to High BMI

Number of deaths related to high BMI is used to estimate the mortality cost of high BMI. In all three years, about 1/3 of total deaths are due to females. Unlike YLD, in 2007, the number of deaths related to high BMI decreased by 2.1% for males and 12.7% for females aged 15-69. Despite the overall reduction, the number of deaths for younger ages increased (males aged 20-39 and females aged 20-34). This increase ranges from 0.5% to 25% among males aged 20-59 and from 3.7% to 30.2% among females aged 20-54 (Tables 3.3 – 3.4). Compared with 2007, in 2017, deaths decreased by 9.4% and 11.8% for males and females, respectively. The decline is observed in all age groups.

As regards the percentage of deaths which are attributable to high BMI (PAF),[27] they range from 0% (ages 15-19) to 19.1% (ages 45-49 in 2007) for males and from 0% (ages 15-19) to 17.6% (ages 65-69 in 1997) for females (Tables 3.3 – 3.4).

Table 3.3: Number, rate and percentage of deaths related to high BMI, males

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	0	0	0	-38.1%	-54.9%	-72.1%
20 to 24	12	12	5	0.5%	-58.4%	-58.2%
25 to 29	23	29	12	25.0%	-59.4%	-49.2%
30 to 34	39	45	31	16.6%	-32.2%	-20.9%
35 to 39	72	87	56	21.0%	-35.6%	-22.1%
40 to 44	118	140	100	19.1%	-28.7%	-15.0%
45 to 49	199	244	208	22.6%	-14.4%	4.9%
50 to 54	288	340	314	17.9%	-7.5%	9.0%
55 to 59	403	442	426	9.7%	-3.7%	5.6%
60 to 64	625	558	536	-10.7%	-3.8%	-14.1%
65 to 69	881	708	672	-19.7%	-5.0%	-23.7%
All Ages	5,608	6,415	6,096	14.4%	-5.0%	8.7%
15 to 69	2,660	2,604	2,360	-2.1%	-9.4%	-11.3%
Rate						
15 to 19	0	0	0	-22.1%	-43.8%	-56.2%
20 to 24	3	3	2	15.7%	-46.6%	-38.2%
25 to 29	5	7	4	25.3%	-44.1%	-30.0%
30 to 34	9	10	8	10.1%	-24.0%	-16.3%
35 to 39	18	20	14	9.5%	-30.7%	-24.1%
40 to 44	32	35	24	8.1%	-29.4%	-23.7%
45 to 49	58	64	53	10.5%	-16.5%	-7.7%
50 to 54	91	98	88	7.6%	-9.9%	-3.1%
55 to 59	133	139	128	4.6%	-7.8%	-3.5%
60 to 64	205	194	178	-5.4%	-8.1%	-13.0%
65 to 69	317	272	247	-14.0%	-9.4%	-22.1%
All Ages	104	117	116	12.7%	-0.3%	12.4%
Percentage						
15 to 19	0%	0%	0%	-4.6%	-26.5%	-29.9%
20 to 24	2.6%	3.1%	2.6%	19.1%	-15.5%	0.7%

[27] Multiplying PAF with the number of deaths we estimate the number of deaths related to high BMI.

Table 3.3: Number, rate and percentage of deaths related to high BMI, males (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Percentage (continued)						
25 to 29	4.6%	5.6%	5.5%	20.6%	-1.9%	18.3%
30 to 34	7.8%	9.6%	9.1%	22.0%	-4.6%	16.5%
35 to 39	12.1%	14.4%	12.9%	18.7%	-10.2%	6.6%
40 to 44	14.8%	16.6%	15.1%	11.9%	-8.9%	2.0%
45 to 49	17.2%	19.1%	18.0%	11.3%	-5.5%	5.2%
50 to 54	17.1%	18.7%	18.2%	9.5%	-2.6%	6.6%
55 to 59	16.7%	17.1%	16.2%	2.5%	-5.3%	-2.9%
60 to 64	15.8%	16.5%	15.2%	4.4%	-7.5%	-3.4%
65 to 69	14.6%	14.9%	13.8%	2.7%	-7.8%	-5.3%
All Ages	10.6%	11.3%	10.5%	7.0%	-7.8%	-1.3%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

Table 3.4: Number, rate and percentage of deaths related to high BMI, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	0	0	0	-30.4%	-44.7%	-61.5%
20 to 24	4	5	3	3.7%	-44.9%	-42.9%
25 to 29	8	10	4	19.4%	-59.3%	-51.5%
30 to 34	14	18	11	25.7%	-35.6%	-19.0%
35 to 39	20	26	19	30.2%	-26.7%	-4.6%
40 to 44	32	38	30	17.7%	-21.1%	-7.1%
45 to 49	52	62	58	21.0%	-7.1%	12.4%
50 to 54	107	113	108	5.8%	-4.6%	1.0%
55 to 59	175	167	158	-4.7%	-4.9%	-9.3%
60 to 64	303	239	218	-21.1%	-8.8%	-28.0%
65 to 69	513	395	336	-23.0%	-14.8%	-34.4%
All Ages	4,414	5,767	5,700	30.6%	-1.2%	29.1%
15 to 69	1,228	1,072	946	-12.7%	-11.8%	-23.0%
Rate						
15 to 19	0	0	0	-11.7%	-34.1%	-41.8%
20 to 24	1	1	1	21.8%	-30.8%	-15.8%
25 to 29	2	2	1	23.4%	-45.3%	-32.5%
30 to 34	3	4	3	22.5%	-29.6%	-13.8%
35 to 39	5	6	5	19.5%	-21.7%	-6.4%
40 to 44	9	9	7	5.8%	-20.6%	-16.0%
45 to 49	15	16	14	6.1%	-9.0%	-3.4%
50 to 54	32	31	29	-3.3%	-8.8%	-11.8%
55 to 59	53	50	45	-6.6%	-9.7%	-15.6%
60 to 64	89	76	69	-14.4%	-10.3%	-23.2%

Table 3.4: Number, rate and percentage of deaths related to high BMI, females (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Rate (continued)						
65 to 69	163	132	112	-18.8%	-15.3%	-31.2%
All Ages	80	103	105	28.3%	2.1%	31.0%
Percentage						
15 to 19	0%	0%	0%	-2.4%	-10.5%	-12.7%
20 to 24	3.8%	5.0%	3.9%	30.2%	-21.4%	2.3%
25 to 29	6.1%	7.9%	5.6%	28.6%	-28.9%	-8.6%
30 to 34	8.4%	11.0%	9.0%	31.1%	-17.5%	8.1%
35 to 39	8.9%	11.2%	9.6%	26.0%	-14.0%	8.3%
40 to 44	9.6%	10.6%	8.9%	10.2%	-15.4%	-6.8%
45 to 49	10.1%	11.0%	10.4%	9.7%	-6.2%	2.9%
50 to 54	14.0%	14.2%	13.2%	0.8%	-7.1%	-6.3%
55 to 59	15.2%	15.2%	13.7%	-0.2%	-10.1%	-10.3%
60 to 64	16.7%	15.9%	14.1%	-4.4%	-11.8%	-15.7%
65 to 69	17.6%	16.4%	14.6%	-6.4%	-11.3%	-17.0%
All Ages	10.8%	11.6%	10.8%	7.4%	-6.9%	-0.1%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.2 YLD and Deaths Related to Dietary Risks

3.2.2.1 YLD Related to Dietary Risks

For the population of our interest, the number of YLDs related to dietary risks increased by 9.1% during the first decade (1997-2007) and 13.3% during the second decade (2007-2017). As it is shown in Tables 3.5 – 3.6, in the first decade, the number of YLDs increased for both gender and all age groups, but people aged 60-69. The same also occurs in the second decade with only exception males and females aged 25-34. Compared to 1997, the number of YLDs rose by 25.5 % for males and 21.2% for females in 2017. The increase occur in all age groups apart from people aged 25-29. In all three years, females bore about 40% of YLDs.

As regards PAFs and rates of YLDs, the general picture shows that both follow an upward trend. PAFs range from 1.7% (ages 25-29 in 1997) to 6.2% (ages 65-69 in 2017) for males and from 1.2% (ages 25-29 in 1997) to 4.2% (ages 65-69 in 2017) for females.

Table 3.5: Number, rate and percentage of YLD related to dietary risks, males

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
25 to 29	688	821	651	19.4%	-20.7%	-5.4%
30 to 34	770	961	854	24.9%	-11.2%	10.9%
35 to 39	859	1,100	1,161	28.1%	5.5%	35.1%
40 to 44	976	1,215	1,396	24.4%	14.9%	43.0%
45 to 49	1,231	1,523	1,836	23.7%	20.6%	49.2%
50 to 54	1,575	1,884	2,240	19.6%	18.9%	42.2%
55 to 59	2,049	2,284	2,762	11.5%	20.9%	34.8%
60 to 64	2,658	2,613	3,132	-1.7%	19.9%	17.8%
65 to 69	2,962	2,824	3,243	-4.7%	14.8%	9.5%
All Ages	19,988	23,735	28,158	18.7%	18.6%	40.9%
25 to 69	13,768	15,226	17,276	10.6%	13.5%	25.5%
Rate						
25 to 29	157	188	228	19.7%	20.9%	44.7%
30 to 34	187	221	262	17.9%	18.9%	40.2%
35 to 39	217	252	297	15.9%	18.0%	36.8%
40 to 44	266	300	352	12.9%	17.1%	32.2%
45 to 49	357	399	464	11.5%	16.4%	29.8%
50 to 54	497	542	625	9.1%	15.3%	25.8%
55 to 59	674	717	813	6.4%	13.4%	20.7%
60 to 64	872	909	1,022	4.2%	12.5%	17.2%
65 to 69	1,065	1,087	1,199	2.2%	10.2%	12.6%
All Ages	369	432	553	17.0%	28.1%	49.8%
Percentage						
25 to 29	1.7%	2.0%	2.4%	19.4%	21.0%	44.5%
30 to 34	1.8%	2.2%	2.6%	17.0%	19.0%	39.3%
35 to 39	2.0%	2.3%	2.7%	14.4%	17.9%	34.9%
40 to 44	2.3%	2.6%	3.0%	11.1%	16.8%	29.7%
45 to 49	2.8%	3.1%	3.6%	9.5%	16.4%	27.5%
50 to 54	3.6%	3.9%	4.4%	7.3%	14.7%	23.1%
55 to 59	4.5%	4.7%	5.2%	4.6%	12.4%	17.5%
60 to 64	5.2%	5.3%	5.9%	2.3%	11.0%	13.5%
65 to 69	5.6%	5.7%	6.2%	0.6%	8.9%	9.6%
All Ages	3.2%	3.5%	4.2%	9.5%	19.0%	30.3%

Notes: Own calculations based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

Table 3.6: Number, rate and percentage of YLD related to dietary risks, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
25 to 29	638	723	584	13.4%	-19.3%	-8.5%
30 to 34	689	812	755	17.9%	-7.1%	9.5%
35 to 39	750	930	1,010	23.9%	8.6%	34.6%
40 to 44	818	1,007	1,167	23.1%	15.8%	42.6%
45 to 49	967	1,195	1,446	23.6%	21.0%	49.6%
50 to 54	1,195	1,381	1,705	15.5%	23.5%	42.6%
55 to 59	1,567	1,653	2,066	5.5%	25.0%	31.8%
60 to 64	2,087	1,952	2,299	-6.5%	17.8%	10.1%
65 to 69	2,403	2,255	2,445	-6.1%	8.4%	1.8%
All Ages	17,259	19,858	23,694	15.1%	19.3%	37.3%
25 to 69	11,114	11,908	13,475	7.1%	13.2%	21.2%
Rate						
25 to 29	151	177	213	17.2%	20.4%	41.1%
30 to 34	170	196	235	14.9%	19.9%	37.8%
35 to 39	190	217	259	13.8%	19.4%	35.9%
40 to 44	223	247	295	10.7%	19.7%	32.4%
45 to 49	280	303	360	8.3%	18.6%	28.5%
50 to 54	363	383	454	5.6%	18.6%	25.2%
55 to 59	477	493	569	3.4%	15.5%	19.4%
60 to 64	614	623	702	1.5%	12.6%	14.3%
65 to 69	764	757	836	-1.0%	10.5%	9.4%
All Ages	313	354	446	13.0%	25.9%	42.3%
Percentage						
25 to 29	1.2%	1.4%	1.7%	15.9%	19.5%	38.5%
30 to 34	1.3%	1.5%	1.8%	13.2%	22.1%	38.2%
35 to 39	1.4%	1.6%	1.9%	11.8%	18.7%	32.7%
40 to 44	1.5%	1.7%	2.0%	10.1%	18.7%	30.8%
45 to 49	1.8%	1.9%	2.3%	7.8%	18.4%	27.6%
50 to 54	2.3%	2.4%	2.8%	4.1%	17.6%	22.4%
55 to 59	2.9%	2.9%	3.4%	1.4%	14.4%	16.0%
60 to 64	3.5%	3.5%	3.9%	-0.3%	11.7%	11.3%
65 to 69	3.9%	3.8%	4.2%	-2.1%	9.9%	7.6%
All Ages	2.3%	2.4%	2.9%	7.0%	19.0%	27.3%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.2.2 Deaths Related to Dietary Risks

With the passing of years, the number of deaths related to dietary risks has changed similarly for the two genders. In all three years, deaths are lower for females than males, accounting for about 1/4 of total deaths. Unlike YLD, in 2007, the number of deaths related to high BMI decreased by 12.6% for males and 20.6% for females aged 25-69. This reduction was caused by the fall in deaths of older population (males aged 60-69 and females aged 55-69) and especially people being in the highest age group (65-69). The second decade, deaths decreased by 6.5% for males but increased by 1.7% for females.

The percentage of deaths related to dietary risks (PAF) has a decline trend for the total population. For males (females) it was 21.7% (20.7%) in 1997, then, in 2007, fell to 20.1% (19.5%) and in 2017 reduced more reaching 19.5% (18.6%) . In the first decade, deaths fell for older people (50-69) while in the second decade the reduction was for all age groups but people ages 50-59. PAFs range from 7.9% (ages 25-29 in 1997) to 29.5% (ages 45-49 in 2017) for males and from 8.5% (ages 25-29 in 2017) to 21.7% (ages 65-69 in 1997) for females (Tables 3.7 – 3.8).

Table 3.7: Number, rate and percentage of deaths related to dietary risks, males

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
25 to 29	39	46	16	15.6%	-64.8%	-59.3%
30 to 34	68	71	38	4.4%	-46.0%	-43.6%
35 to 39	127	138	90	8.1%	-34.5%	-29.2%
40 to 44	210	227	159	8.2%	-30.1%	-24.4%
45 to 49	335	376	315	12.2%	-16.3%	-6.0%
50 to 54	482	509	493	5.5%	-3.2%	2.1%
55 to 59	654	659	668	0.8%	1.3%	2.1%
60 to 64	1,003	790	826	-21.2%	4.6%	-17.6%
65 to 69	1,462	1,015	978	-30.6%	-3.7%	-33.1%
All Ages	11,495	11,382	12,269	-1.0%	7.8%	6.7%
25 to 69	4,381	3,830	3,582	-12.6%	-6.5%	-18.2%
Rate						
25 to 29	9	10	6	15.8%	-46.2%	-37.7%
30 to 34	17	16	12	-1.4%	-27.7%	-28.7%
35 to 39	32	32	23	-2.1%	-26.7%	-28.3%
40 to 44	57	56	40	-1.8%	-28.8%	-30.1%
45 to 49	97	98	80	1.2%	-19.2%	-18.2%
50 to 54	152	146	137	-3.8%	-6.1%	-9.7%
55 to 59	215	207	197	-3.8%	-5.0%	-8.6%
60 to 64	329	275	270	-16.5%	-1.9%	-18.0%
65 to 69	525	391	361	-25.6%	-7.5%	-31.2%
All Ages	212	207	241	-2.4%	16.4%	13.5%

Table 3.7: Number, rate and percentage of deaths related to dietary risks, males (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Percentage						
25 to 29	7.9%	8.8%	8.2%	11.5%	-6.4%	4.4%
30 to 34	13.8%	15.1%	14.3%	9.3%	-5.1%	3.7%
35 to 39	21.6%	22.9%	21.3%	6.0%	-7.0%	-1.4%
40 to 44	26.5%	27.0%	25.5%	1.7%	-5.4%	-3.8%
45 to 49	28.9%	29.5%	29.0%	1.9%	-1.6%	0.3%
50 to 54	28.5%	27.9%	28.7%	-2.0%	2.6%	0.5%
55 to 59	27.0%	25.4%	25.8%	-5.8%	1.3%	-4.6%
60 to 64	25.3%	23.3%	23.0%	-7.9%	-1.5%	-9.2%
65 to 69	24.1%	21.4%	20.9%	-11.2%	-2.6%	-13.5%
All Ages	21.7%	20.1%	19.5%	-7.4%	-2.9%	-10.1%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

Table 3.8: Number, rate and percentage of deaths related to dietary risks, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
25 to 29	14	14	6	0.6%	-59.3%	-59.1%
30 to 34	22	23	16	8.5%	-33.0%	-27.3%
35 to 39	32	37	26	14.7%	-28.3%	-17.7%
40 to 44	51	56	51	10.2%	-9.6%	-0.3%
45 to 49	81	91	90	11.7%	-1.4%	10.1%
50 to 54	121	125	138	4.0%	9.9%	14.3%
55 to 59	197	173	199	-12.0%	14.7%	1.0%
60 to 64	356	255	278	-28.4%	9.2%	-21.8%
65 to 69	635	423	415	-33.4%	-1.9%	-34.6%
All Ages	8,483	9,715	10,707	14.5%	10.2%	26.2%
15 to 69	1,508	1,197	1,218	-20.6%	1.7%	-19.2%
Rate						
25 to 29	3	3	2	4.0%	-39.3%	-36.9%
30 to 34	5	6	5	5.7%	-13.5%	-8.6%
35 to 39	8	9	7	5.3%	-21.1%	-16.9%
40 to 44	14	14	13	-1.0%	-6.6%	-7.5%
45 to 49	24	23	22	-2.1%	-3.4%	-5.5%
50 to 54	37	35	37	-4.9%	5.6%	0.4%
55 to 59	60	52	55	-13.7%	6.0%	-8.5%
60 to 64	105	81	85	-22.3%	4.5%	-18.8%
65 to 69	202	142	142	-29.7%	-0.1%	-29.7%
All Ages	154	173	201	12.5%	16.3%	30.8%

Table 3.8: Number, rate and percentage of deaths related to dietary risks, females (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Percentage						
25 to 29	10.2%	11.1%	8.5%	8.4%	-23.5%	-17.1%
30 to 34	12.8%	14.4%	12.8%	13.2%	-11.3%	0.4%
35 to 39	14.0%	15.5%	13.6%	11.0%	-12.1%	-2.5%
40 to 44	15.3%	15.7%	14.4%	3.2%	-8.7%	-5.8%
45 to 49	15.9%	16.1%	15.7%	1.2%	-2.4%	-1.2%
50 to 54	15.9%	15.8%	15.8%	-0.9%	0.1%	-0.8%
55 to 59	17.1%	15.8%	15.8%	-7.8%	0.2%	-7.7%
60 to 64	19.6%	17.0%	16.2%	-13.3%	-4.7%	-17.3%
65 to 69	21.7%	17.6%	17.2%	-19.0%	-2.2%	-20.8%
All Ages	20.7%	19.5%	18.6%	-5.9%	-4.6%	-10.2%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.3 YLD and Deaths Related to Smoking

3.2.3.1 YLD Related to Smoking

To estimate the morbidity cost of smoking, we use the number of YLDs related to smoking. There are significant differences among age groups and genders. YLDs are higher for males than females but the burden for females has an increasing trend. Taking into account only the population of our interest, in 1997, 42.1% of total YLDs was due to females while the corresponding proportion in 2007 and 2017 was 44.5% and 47.5%, respectively. During the first decade (1997-2007), the number of YLDs increased by 10.7% for females and only by 0.4% for males (Tables 3.9 – 3.10). This is due to the increase of YLDs for ages 35-59. In the second decade (2007-2017), the YLDs continued to increase for females (9.6%) but decreased for males (4.0%). YLDs increased for females aged 45-69 and only for older males aged 60-69. A twenty-year comparison (1997-2017) shows that there is a significant increase for females (21.3%), especially for those aged 45-59. On the other hand, males' YLDs decreased (3.6%) especially for ages 30-39.

To compare the YLDs among years, it is more appropriate to use the rate of YLDs (per 100,000 population) so as to take into account changes in population. For males, rates have a decreasing trend as the number of YLDs but this occur for more age groups (Tables 3.9 – 3.10). For females, rates have increased with only exception the first three age groups. The same pattern also occurs in the percentage of YLD attributed to smoking (PAFs[28]). For males, PAFs ranged from 7.7% (ages 30-34 in 2017) to 17.3% (ages 65-69 in 1997). PAFs for females are lower ranging from 6.1% (ages 30-34 in 2017) to 11.7% (ages 55-59 and 65-69 in 2017).

Table 3.9: Number, rate and percentage of YLD related to smoking, males

	1997	**2007**	**2017**	**% change 1997-2007**	**% change 2007-2017**	**% change 1997-2017**
Number						
30 to 34	3,980	3,938	2,576	-1.1%	-34.6%	-35.3%
35 to 39	4,580	4,712	3,829	2.9%	-18.7%	-16.4%
40 to 44	5,211	5,337	4,867	2.4%	-8.8%	-6.6%
45 to 49	5,722	6,221	5,941	8.7%	-4.5%	3.8%
50 to 54	6,270	6,872	6,568	9.6%	-4.4%	4.8%
55 to 59	7,097	7,641	7,637	7.7%	0.0%	7.6%
60 to 64	8,557	7,908	8,674	-7.6%	9.7%	1.4%
65 to 69	9,041	8,034	8,564	-11.1%	6.6%	-5.3%
All Ages	70,625	77,402	78,109	9.6%	0.9%	10.6%
30-69	50,458	50,662	48,656	0.4%	-4.0%	-3.6%
Rate						
30 to 34	967	904	792	-6.6%	-12.4%	-18.2%
35 to 39	1,158	1,078	980	-6.9%	-9.1%	-15.3%
40 to 44	1,420	1,320	1,226	-7.1%	-7.1%	-13.7%
45 to 49	1,662	1,628	1,501	-2.0%	-7.8%	-9.6%
50 to 54	1,977	1,976	1,832	0.0%	-7.3%	-7.4%
55 to 59	2,335	2,399	2,248	2.7%	-6.3%	-3.7%
60 to 64	2,807	2,750	2,831	-2.0%	2.9%	0.9%
65 to 69	3,250	3,094	3,166	-4.8%	2.3%	-2.6%
All Ages	1,305	1,409	1,535	8.0%	8.9%	17.6%
Percentage						
30 to 34	9.5%	8.8%	7.7%	-7.3%	-12.4%	-18.8%
35 to 39	10.8%	9.9%	9.0%	-8.1%	-9.2%	-16.5%
40 to 44	12.3%	11.3%	10.4%	-8.6%	-7.4%	-15.3%
45 to 49	13.3%	12.8%	11.8%	-3.7%	-7.8%	-11.2%
50 to 54	14.3%	14.1%	13.0%	-1.6%	-7.7%	-9.2%
55 to 59	15.5%	15.6%	14.5%	1.0%	-7.1%	-6.1%
60 to 64	16.8%	16.2%	16.4%	-3.8%	1.6%	-2.3%
65 to 69	17.3%	16.2%	16.4%	-6.2%	1.1%	-5.1%
All Ages	11.5%	11.6%	11.8%	1.1%	1.3%	2.4%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

[28] Multiplying PAF with the number of YLDs we estimate the number of YLDs related to smoking.

Table 3.10: Number, rate and percentage of YLD related to smoking, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
30 to 34	3,869	3,568	2,554	-7.8%	-28.4%	-34.0%
35 to 39	4,275	4,329	3,973	1.2%	-8.2%	-7.1%
40 to 44	4,652	5,008	4,745	7.6%	-5.2%	2.0%
45 to 49	4,439	5,693	6,152	28.2%	8.1%	38.6%
50 to 54	4,297	6,196	6,847	44.2%	10.5%	59.4%
55 to 59	4,273	5,188	7,186	21.4%	38.5%	68.1%
60 to 64	5,605	5,526	6,933	-1.4%	25.5%	23.7%
65 to 69	5,351	5,193	6,217	-3.0%	19.7%	16.2%
All Ages	47,750	53,190	60,635	11.4%	14.0%	27.0%
15-69	36,762	40,700	44,609	10.7%	9.6%	21.3%
Rate						
30 to 34	956	859	794	-10.1%	-7.6%	-17.0%
35 to 39	1,085	1,008	1,018	-7.0%	0.9%	-6.2%
40 to 44	1,267	1,226	1,200	-3.3%	-2.1%	-5.3%
45 to 49	1,285	1,444	1,530	12.4%	5.9%	19.0%
50 to 54	1,303	1,719	1,824	31.9%	6.1%	40.0%
55 to 59	1,301	1,547	1,981	19.0%	28.0%	52.3%
60 to 64	1,649	1,764	2,117	7.0%	20.0%	28.4%
65 to 69	1,701	1,742	2,125	2.4%	22.0%	24.9%
All Ages	867	949	1,141	9.4%	20.3%	31.6%
Percentage						
30 to 34	7.3%	6.5%	6.1%	-11.5%	-5.9%	-16.7%
35 to 39	8.0%	7.3%	7.3%	-8.6%	0.4%	-8.3%
40 to 44	8.5%	8.2%	8.0%	-3.7%	-2.8%	-6.4%
45 to 49	8.3%	9.3%	9.8%	11.8%	5.6%	18.1%
50 to 54	8.3%	10.8%	11.3%	29.9%	5.2%	36.6%
55 to 59	7.9%	9.3%	11.7%	16.7%	26.7%	47.9%
60 to 64	9.4%	9.8%	11.7%	5.1%	19.0%	25.1%
65 to 69	8.8%	8.9%	10.8%	1.2%	21.4%	22.9%
All Ages	6.4%	6.6%	7.5%	3.6%	13.7%	17.8%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.3.2 Deaths Related to Smoking

Number of deaths related to smoking is used to estimate the mortality cost of smoking. As with YLDs, there are significant differences between genders. Compared to males, smoking-attributable deaths are much lower for females but their burden follows an upward trend. Specifically, while in 1997 female deaths were 19.2% of total deaths (for the population of our interest), in 2007 and 2017 the corresponding proportions were 20.6% and 25.3%, respectively.

The general picture of male deaths shows a decreasing trend (Table 3.11). Compared to 1997, males deaths decreased by 11.6% in 2007 and 19.2% in 2017. Deaths increased only for male aged 45-59 in the first decade and 60-64 in the second decade. On the other hand, the picture for females is different (Table 3.12). In 2007, female deaths decreased slightly (3.3%) and this is mainly due to females aged 60-69. In the second decade, female deaths increased by 18.7%, despite the reduction at ages 30-49 (deaths at those ages are much lower than ones at older ages).

The death rates and PAFs related to smoking followed a decreasing trend for males of all age groups with only exception males aged 55-59 in 2007. For females, the pattern was similar with the number of deaths. PAFs range from 9.7% (ages 30-34 in 2017) to 49.0% (ages 60-64 in 1997) for males and from 10.6% (ages 30-34 in 2017) to 31.2% (ages50-54 in 2017) for females (Tables 3.11 – 3.12).

Table 3.11: Number, rate and percentage of deaths related to smoking, males

	1997	**2007**	**2017**	**% change 1997-2007**	**% change 2007-2017**	**% change 1997-2017**
Number						
30 to 34	59	55	26	-7.1%	-52.3%	-55.6%
35 to 39	134	127	74	-5.1%	-41.9%	-44.8%
40 to 44	271	252	158	-7.0%	-37.2%	-41.6%
45 to 49	491	509	368	3.5%	-27.7%	-25.2%
50 to 54	794	833	683	5.0%	-18.0%	-13.9%
55 to 59	1,139	1,235	1,096	8.4%	-11.2%	-3.8%
60 to 64	1,944	1,641	1,703	-15.6%	3.8%	-12.4%
65 to 69	2,744	2,045	2,011	-25.5%	-1.7%	-26.7%
All Ages	17,813	18,767	18,332	5.4%	-2.3%	2.9%
30 to 69	7,577	6,696	6,119	-11.6%	-8.6%	-19.2%
Rate						
30 to 34	14	13	8	-12.2%	-36.1%	-43.9%
35 to 39	34	29	19	-14.1%	-35.0%	-44.1%
40 to 44	74	62	40	-15.7%	-36.0%	-46.0%
45 to 49	143	133	93	-6.7%	-30.2%	-34.9%
50 to 54	250	240	191	-4.2%	-20.5%	-23.9%
55 to 59	375	388	323	3.4%	-16.8%	-13.9%
60 to 64	638	571	556	-10.5%	-2.6%	-12.9%
65 to 69	986	787	743	-20.2%	-5.6%	-24.6%
All Ages	329	342	360	3.8%	5.4%	9.5%

Table 3.11: Number, rate and percentage of deaths related to smoking, males (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Percentage						
30 to 34	11.9%	11.6%	9.7%	-2.7%	-16.2%	-18.5%
35 to 39	22.7%	21.1%	17.4%	-6.9%	-17.5%	-23.2%
40 to 44	34.2%	29.9%	25.4%	-12.6%	-14.9%	-25.7%
45 to 49	42.4%	39.9%	33.9%	-6.0%	-15.1%	-20.2%
50 to 54	46.9%	45.8%	39.8%	-2.5%	-13.1%	-15.3%
55 to 59	47.1%	47.7%	42.3%	1.3%	-11.3%	-10.1%
60 to 64	49.0%	48.4%	47.3%	-1.2%	-2.3%	-3.5%
65 to 69	45.3%	43.2%	42.9%	-4.7%	-0.6%	-5.2%
All Ages	33.7%	33.2%	29.2%	-1.4%	-12.0%	-13.3%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

Table 3.12: Number, rate and percentage of deaths related to smoking, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
30 to 34	23	21	13	-6.7%	-39.2%	-43.2%
35 to 39	43	43	30	1.4%	-31.4%	-30.5%
40 to 44	81	83	70	2.7%	-15.9%	-13.6%
45 to 49	123	152	152	23.9%	-0.5%	23.3%
50 to 54	185	247	272	33.7%	10.3%	47.5%
55 to 59	244	278	385	14.2%	38.3%	57.9%
60 to 64	465	403	522	-13.3%	29.4%	12.3%
65 to 69	638	513	624	-19.6%	21.7%	-2.2%
All Ages	4,775	5,190	6,069	8.7%	16.9%	27.1%
30 to 69	1,800	1,741	2,067	-3.3%	18.7%	14.8%
Rate						
30 to 34	6	5	4	-9.1%	-21.5%	-28.6%
35 to 39	11	10	8	-6.9%	-24.6%	-29.8%
40 to 44	22	20	18	-7.7%	-13.1%	-19.8%
45 to 49	36	39	38	8.6%	-2.5%	5.9%
50 to 54	56	68	73	22.3%	6.0%	29.5%
55 to 59	74	83	106	11.9%	27.8%	43.0%
60 to 64	137	129	159	-5.9%	23.8%	16.5%
65 to 69	203	172	213	-15.2%	23.9%	5.2%
All Ages	87	93	114	6.8%	23.4%	31.7%
Percentage						
30 to 34	13.5%	13.2%	10.6%	-2.7%	-19.5%	-21.6%
35 to 39	18.7%	18.4%	15.4%	-2.0%	-16.0%	-17.6%
40 to 44	24.3%	23.3%	19.8%	-3.8%	-15.1%	-18.4%

Table 3.12 : Number, rate and percentage of deaths related to smoking, females (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Percentage (continued)						
45 to 49	24.0%	26.9%	26.5%	12.3%	-1.5%	10.7%
50 to 54	24.3%	31.0%	31.2%	27.4%	0.5%	28.0%
55 to 59	21.3%	25.4%	30.7%	19.6%	20.8%	44.4%
60 to 64	25.6%	26.9%	30.3%	5.1%	12.9%	18.7%
65 to 69	21.8%	21.3%	25.9%	-2.2%	21.3%	18.6%
All Ages	11.7%	10.4%	10.6%	-10.7%	1.2%	-9.6%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.4 YLD and Deaths Related to SHS Exposure

3.2.4.1 YLD Related to SHS Exposure

As shown in Tables 3.13 – 3.14, the number of YLDs related to SHS exposure is negligible for both males and females aged 15-24. During the first decade, the number of YLDs increased for males aged 25-69 and females aged 30-54. In the second decade, the increase was smaller and in fewer age groups. Specifically, in 2017, YLDs increased for males aged 40-69 and females aged 40-64. In total, males show an increasing trend in YLDs while the opposite occurs for females. Compared to 1997, the number of YLD for males increased by 17.4% in 2007 and 20.8% in 2017. On the other hand, the corresponding change for females was -1.8% and -2.7%, respectively. However, for all three years, YLDs are higher for females than males.

As regards PAFs related to SHS exposure, they are relatively low as the maximum is 1.6% for males (ages 60-64 in 2007 and 2017) and 1.5% for females (ages 65-69 in 1997 and 2007). As with the number of YLDs, PAFs follow an increasing/decreasing trend for the most male/female age groups. The same pattern is also observed in YLD rates (Tables 3.13 – 3.14).

Table 3.13: Number, rate and percentage of YLD related to SHS exposure, males

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	1	1	0	-32.6%	-24.7%	-49.2%
20 to 24	1	0	0	-24.3%	-31.8%	-48.4%
25 to 29	122	147	108	20.4%	-26.2%	-11.2%
30 to 34	131	165	131	26.4%	-20.7%	0.2%
35 to 39	138	178	170	29.0%	-4.2%	23.6%

Table 3.13: Number, rate and percentage of YLD related to SHS exposure, males (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number (continued)						
40 to 44	188	240	247	27.8%	3.0%	31.6%
45 to 49	266	346	372	29.9%	7.5%	39.7%
50 to 54	385	493	529	28.1%	7.2%	37.3%
55 to 59	537	653	712	21.5%	9.0%	32.5%
60 to 64	741	799	831	7.9%	4.1%	12.2%
65 to 69	656	693	723	5.6%	4.2%	10.1%
All Ages	4,492	5,692	6,011	26.7%	5.6%	33.8%
15 to 69	3,166	3,716	3,825	17.4%	2.9%	20.8%
Rate						
15 to 19	0	0	0	-15.0%	-3.5%	-18.0%
20 to 24	0	0	0	-12.8%	-2.0%	-14.6%
25 to 29	28	34	38	20.7%	12.5%	35.8%
30 to 34	32	38	40	19.4%	6.2%	26.7%
35 to 39	35	41	44	16.8%	7.2%	25.2%
40 to 44	51	59	62	15.9%	4.9%	21.6%
45 to 49	77	91	94	17.1%	3.8%	21.6%
50 to 54	121	142	147	16.9%	3.9%	21.5%
55 to 59	177	205	210	15.9%	2.2%	18.5%
60 to 64	243	278	271	14.4%	-2.4%	11.7%
65 to 69	236	267	267	13.2%	0.1%	13.2%
All Ages	83	104	118	24.8%	14.0%	42.3%
Percentage						
15 to 19	0.0%	0.0%	0.0%	-16.6%	-4.5%	-20.4%
20 to 24	0.0%	0.0%	0.0%	-13.4%	-2.1%	-15.2%
25 to 29	0.3%	0.4%	0.4%	20.2%	12.5%	35.3%
30 to 34	0.3%	0.4%	0.4%	18.3%	6.2%	25.6%
35 to 39	0.3%	0.4%	0.4%	15.2%	7.2%	23.5%
40 to 44	0.4%	0.5%	0.5%	14.0%	4.7%	19.3%
45 to 49	0.6%	0.7%	0.7%	14.8%	3.7%	19.1%
50 to 54	0.9%	1.0%	1.1%	14.9%	3.5%	19.0%
55 to 59	1.2%	1.3%	1.4%	13.9%	1.4%	15.5%
60 to 64	1.5%	1.6%	1.6%	12.1%	-3.7%	8.0%
65 to 69	1.3%	1.4%	1.4%	11.3%	-1.2%	9.9%
All Ages	0.7%	0.9%	0.9%	16.8%	6.0%	23.7%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

Table 3.14: Number, rate and percentage of YLD related to SHS exposure, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	1	0	0	-36.7%	-21.9%	-50.6%
20 to 24	1	0	0	-33.7%	-28.2%	-52.4%
25 to 29	176	175	126	-0.1%	-27.9%	-28.0%
30 to 34	200	207	169	3.6%	-18.6%	-15.8%
35 to 39	233	251	239	7.9%	-4.8%	2.8%
40 to 44	275	295	307	7.5%	4.0%	11.8%
45 to 49	401	446	475	11.4%	6.4%	18.5%
50 to 54	536	575	610	7.3%	6.1%	13.8%
55 to 59	656	646	702	-1.5%	8.7%	7.1%
60 to 64	864	762	768	-11.8%	0.7%	-11.1%
65 to 69	941	847	771	-10.0%	-8.9%	-18.0%
All Ages	6,705	7,236	7,514	7.9%	3.9%	12.1%
15-69	4,281	4,205	4,167	-1.8%	-0.9%	-2.7%
Rate						
15 to 19	0	0	0	-19.7%	-4.5%	-23.3%
20 to 24	0	0	0	-22.2%	-1.5%	-23.3%
25 to 29	42	43	46	3.2%	7.6%	11.0%
30 to 34	50	50	52	0.9%	5.0%	6.0%
35 to 39	59	58	61	-0.9%	4.7%	3.8%
40 to 44	75	72	78	-3.4%	7.5%	3.8%
45 to 49	116	113	118	-2.4%	4.3%	1.8%
50 to 54	163	160	162	-1.9%	1.8%	-0.1%
55 to 59	200	193	193	-3.5%	0.5%	-3.0%
60 to 64	254	243	234	-4.3%	-3.7%	-7.8%
65 to 69	299	284	264	-5.0%	-7.2%	-11.9%
All Ages	122	129	141	6.0%	9.6%	16.1%
Percentage						
15 to 19	0.0%	0.0%	0.0%	-20.8%	-5.2%	-25.0%
20 to 24	0.0%	0.0%	0.0%	-23.2%	-2.0%	-24.7%
25 to 29	0.3%	0.4%	0.4%	2.0%	6.8%	9.0%
30 to 34	0.4%	0.4%	0.4%	-0.7%	7.0%	6.2%
35 to 39	0.4%	0.4%	0.4%	-2.8%	4.1%	1.3%
40 to 44	0.5%	0.5%	0.5%	-3.9%	6.6%	2.4%
45 to 49	0.8%	0.7%	0.8%	-3.1%	4.1%	0.9%
50 to 54	1.0%	1.0%	1.0%	-3.4%	0.9%	-2.5%
55 to 59	1.2%	1.2%	1.1%	-5.5%	-0.5%	-5.9%
60 to 64	1.4%	1.4%	1.3%	-6.0%	-4.4%	-10.1%
65 to 69	1.5%	1.5%	1.3%	-6.2%	-7.7%	-13.5%
All Ages	0.9%	0.9%	0.9%	0.3%	3.6%	3.9%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.4.2 Deaths Related to SHS Exposure

With the passing of years, the number of deaths related to SHS exposure steadily decreased for both genders. Compared to 1997, male deaths decreased by 11.7% in 2007 and 24.5% in 2017. The corresponding decline for females was 22.2% and 24.8%, respectively. Despite the overall reduction, deaths increased for some age groups during the first (ages 25-39 and 45-59 for males and 45-49 for females) and second (ages 50-64 for females) decade. As with YLDs, the number of deaths related to SHS exposure is negligible for both males and females aged 15-24. Female deaths are about 1/3 of total deaths (Tables 3.15 – 3.16).

When we examine the rate and percentage of deaths related to SHS exposure, the declining trend is observed in more age groups. For people aged 15-24, both death rates and PAFs are low and, due to rounding, changes could not be clear in columns 2-4 of Tables 3.15 – 3.16. PAFs range from 0.1 (ages 20-24) to 4.9 (ages 55-64 in 1997) for males and from 0.3 (ages 20-24) to 4.4 (ages 50-54 in 1997).

Table 3.15: Number, rate and percentage of deaths related to SHS exposure, males

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	1	0	0	-43.6%	-42.1%	-67.4%
20 to 24	0	0	0	-22.4%	-36.8%	-50.9%
25 to 29	6	6	2	11.8%	-64.8%	-60.7%
30 to 34	8	8	4	0.1%	-49.1%	-49.0%
35 to 39	14	14	9	1.5%	-37.8%	-36.8%
40 to 44	27	27	17	-0.8%	-35.6%	-36.1%
45 to 49	50	52	38	4.7%	-26.5%	-23.1%
50 to 54	82	83	70	1.9%	-15.7%	-14.1%
55 to 59	118	122	109	3.4%	-10.5%	-7.5%
60 to 64	193	160	146	-17.1%	-8.5%	-24.2%
65 to 69	218	159	143	-27.1%	-9.6%	-34.1%
All Ages	1,405	1,424	1,327	1.3%	-6.8%	-5.6%
15 to 69	717	633	541	-11.7%	-14.5%	-24.5%
Rate						
15 to 19	0.2	0.1	0.1	-28.9%	-25.9%	-47.3%
20 to 24	0.1	0.1	0.1	-10.6%	-9.1%	-18.8%
25 to 29	1.3	1.4	0.8	12.1%	-46.4%	-39.9%
30 to 34	2.0	1.9	1.3	-5.5%	-31.8%	-35.5%
35 to 39	3.6	3.3	2.3	-8.1%	-30.4%	-36.0%
40 to 44	7.5	6.7	4.4	-10.1%	-34.4%	-41.0%
45 to 49	14.5	13.7	9.7	-5.6%	-29.0%	-33.0%
50 to 54	25.8	23.9	19.6	-7.0%	-18.3%	-24.0%

Table 3.15: Number, rate and percentage of deaths related to SHS exposure, males (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Rate (continued)						
55 to 59	38.9	38.4	32.2	-1.3%	-16.1%	-17.2%
60 to 64	63.4	55.7	47.8	-12.1%	-14.2%	-24.6%
65 to 69	78.3	61.1	53.0	-21.9%	-13.3%	-32.3%
All Ages	26.0	25.9	26.1	-0.2%	0.6%	0.4%
Percentage						
15 to 19	0.3%	0.3%	0.3%	-13.0%	15.6%	0.6%
20 to 24	0.1%	0.1%	0.1%	-8.0%	50.6%	38.5%
25 to 29	1.1%	1.2%	1.1%	7.9%	-6.6%	0.7%
30 to 34	1.7%	1.8%	1.6%	4.8%	-10.5%	-6.3%
35 to 39	2.4%	2.4%	2.1%	-0.5%	-11.6%	-12.0%
40 to 44	3.5%	3.2%	2.8%	-6.8%	-12.8%	-18.7%
45 to 49	4.3%	4.1%	3.5%	-4.9%	-13.6%	-17.9%
50 to 54	4.8%	4.6%	4.1%	-5.4%	-10.7%	-15.5%
55 to 59	4.9%	4.7%	4.2%	-3.3%	-10.6%	-13.5%
60 to 64	4.9%	4.7%	4.1%	-3.1%	-13.9%	-16.5%
65 to 69	3.6%	3.4%	3.1%	-6.8%	-8.6%	-14.8%
All Ages	2.7%	2.5%	2.1%	-5.2%	-16.1%	-20.4%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

Table 3.16: Number, rate and percentage of deaths related to SHS exposure, females

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Number						
15 to 19	0	0	0	-36.6%	-24.2%	-51.9%
20 to 24	0	0	0	-26.9%	-28.8%	-48.0%
25 to 29	3	3	1	-10.6%	-57.9%	-62.4%
30 to 34	4	4	3	-4.8%	-35.8%	-38.9%
35 to 39	7	6	5	-1.3%	-30.2%	-31.1%
40 to 44	11	10	9	-6.0%	-9.9%	-15.3%
45 to 49	21	21	19	0.1%	-7.0%	-6.9%
50 to 54	33	32	32	-2.3%	0.2%	-2.1%
55 to 59	47	40	44	-14.5%	8.7%	-7.1%
60 to 64	77	55	58	-28.1%	4.0%	-25.2%
65 to 69	119	79	72	-34.3%	-8.7%	-40.0%
All Ages	1,300	1,391	1,365	7.0%	-1.8%	5.0%
15 to 69	323	251	243	-22.2%	-3.4%	-24.8%
Rate						
15 to 19	0.1	0.1	0.1	-19.6%	-7.2%	-25.4%
20 to 24	0.1	0.1	0.1	-14.1%	-2.4%	-16.2%
25 to 29	0.7	0.6	0.4	-7.6%	-37.3%	-42.0%

Table 3.16: Number, rate and percentage of deaths related to SHS exposure, females (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Rate (continued)						
30 to 34	1.1	1.0	0.8	-7.3%	-17.1%	-23.1%
35 to 39	1.7	1.5	1.2	-9.4%	-23.2%	-30.5%
40 to 44	3.0	2.5	2.3	-15.5%	-6.9%	-21.3%
45 to 49	6.0	5.3	4.8	-12.3%	-8.9%	-20.1%
50 to 54	10.1	9.0	8.7	-10.6%	-3.7%	-14.0%
55 to 59	14.4	12.0	12.1	-16.2%	0.5%	-15.9%
60 to 64	22.6	17.7	17.6	-22.0%	-0.5%	-22.4%
65 to 69	38.0	26.4	24.5	-30.6%	-7.0%	-35.5%
All Ages	23.6	24.8	25.7	5.1%	3.6%	8.8%
Percentage						
15 to 19	0.5%	0.5%	0.5%	-11.0%	15.8%	3.0%
20 to 24	0.3%	0.3%	0.3%	-8.2%	9.1%	0.1%
25 to 29	2.1%	2.1%	1.6%	-3.7%	-20.9%	-23.8%
30 to 34	2.6%	2.6%	2.2%	-0.7%	-14.9%	-15.6%
35 to 39	2.9%	2.8%	2.4%	-4.6%	-14.5%	-18.4%
40 to 44	3.3%	2.9%	2.6%	-12.0%	-9.0%	-19.9%
45 to 49	4.1%	3.7%	3.4%	-9.2%	-8.0%	-16.4%
50 to 54	4.4%	4.1%	3.7%	-6.8%	-8.7%	-14.9%
55 to 59	4.1%	3.7%	3.5%	-10.5%	-5.0%	-15.0%
60 to 64	4.2%	3.7%	3.3%	-12.9%	-9.2%	-20.9%
65 to 69	4.1%	3.3%	3.0%	-20.0%	-9.0%	-27.3%
All Ages	3.2%	2.8%	2.4%	-12.1%	-15.0%	-25.3%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.5 PAFs for Direct Cost Estimation

For the estimation of direct cost, we use the percentage of deaths which are attributable to each risk factor (PAF) for the total population (i.e. both gender and all ages). As shown in Table 3.17, with the passing of years, PAFs fell for all risk factors but high BMI. For high BMI, PAF increased in 2007 but then decreased again to lower than 1997 levels. Among the five risk factors, tobacco use has the highest PAF (from 21.7% in 2017 to 25.8% in 1997), followed by smoking (from 19.1% in 2017 to 24.1% in 1997) and dietary risks (from 19.1% in 2017 to 21.3% in 1997). PAF of high BMI is about the half (from 10.3% in 2017 to 11.5% in 2007) while PAF of SHS is much lower (from 2.2% in 2017 to 2.9% in 1997).

Table 3.17: PAFs for direct cost estimation

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Smoking	24.1%	22.5%	19.1%	-6.6%	-15.1%	-20.7%
SHS exposure	2.9%	2.6%	2.2%	-10.3%	-15.4%	-24.1%
Tobacco	25.8%	24.2%	21.7%	-6.2%	-10.3%	-15.9%
High BMI	10.7%	11.5%	10.3%	7.5%	-10.4%	-3.7%
Dietary risks	21.3%	19.8%	19.1%	-7.0%	-3.5%	-10.3%

Notes: Own calculations, based on data from 2017 GBD study (Global Burden of Disease Collaborative Network, 2018). Calculations are based on the actual numbers and not the rounded ones presented in this table.

3.2.6 Healthcare Expenditures

In 2007, total healthcare expenditures were €21,869 million, increased by 73% compared to 1997. At the same period, government healthcare expenditures almost doubled, reaching €13,528 million. In 2017, both total and government healthcare expenditures decreased by about a third, accounting for €14,492 million and €8,816 million, respectively. Government healthcare expenditures were more than half of total healthcare expenditures (53.9% in 1997, 61.9% in 2007 and 60.8% in 2017). The rest of healthcare expenditures were mostly out-of-pocket spending (Table 3.18).

Table 3.18: Healthcare expenditures in constant 2017 million €

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Total	12,640	21,869	14,492	73.0%	-33.7%	14.7%
Govt expenditure	6,813	13,528	8,816	98.6%	-34.8%	29.4%
Govt exp. as % of total	53.9%	61.9%	60.8%			

Source: OECD (OECD, 2020a)

3.2.7 GDP per Worker

As mentioned, indirect costs represent the value of lost productivity due to morbidity and early mortality. Labour productivity is presented by GDP per worker which is gross domestic product (GDP) divided by total employment in the economy in a given year. For that reason, we calculated indirect costs using GDP per worker instead of earnings/wages as Goodchild et al. (2018) did.

GDP per worker was €42,626 in 1997 and increased by 24.1% in 2007 reaching €52,885. The Greek financing crisis, which started in 2009, had as a result the steadily decrease in GDP and employment rates (Mavridis, 2018). Compared to 2007, in 2017, GDP decreased by 25.3% and the number of workers by 17.8%. Thus, the GDP per worker decreased by 9.2%, reaching €48,024 (Table 3.19).

Table 3.19: GDP per worker

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
GDP	164,283	241,371	180,218	46.9	-25.3	9.7
Workers	3,854	4,564	3,753	18.4	-17.8	-2.6
GDP/Worker	42,626	52,885	48,024	24.1	-9.2	12.7

Notes: Notes: Own calculations, based on data from October 2019 World Economic Outlook database (IMF, 2019) and ELSTAT (2017). Number of workers is in thousands. GDP is in million € and GDP per worker in €. Both GDP and GDP per worker are in constant prices 2017.

3.2.8 Employment to Population Ratio

The employment to population ratio measures the proportion of the working age population employed. It is calculated by dividing the number of people employed by the total number of people of working age. In Table 3.20, the employment to population ratio by gender and age group for years 1997, 2007 and 2017 is presented (OECD, 2020b). The ratio is higher for males for all years and age groups. For both males and females, the ratio is higher for middle-aged population (30-54) and lower for younger and older age groups, creating a bell-shaped curve (Graph 3.1). Compared to 1997, the employment to population ratio in 2007 was increased significantly for females but it was almost the same for males. Only exception for both genders is the younger ages (15 to 24), for which the ratio declined. Regarding the most recent year, 2017, there is a declining trend for both genders with only exception females aged 45-59 and 65-69. This reduction is due to the Greek financial crisis which increased the unemployment rates, especially for younger population (Mavridis, 2018).

Table 3.20: Employment to population ratio (%) by gender and age

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Males						
15 to 19	11.3	9.3	3.3	-17.9	-64.1	-70.5
20 to 24	52.8	46.8	28.6	-11.5	-38.9	-45.9
25 to 29	81.5	81.3	64.7	-0.2	-20.4	-20.6
30 to 34	91.5	91.9	75.9	0.4	-17.4	-17.0
35 to 39	94.1	94.3	81.6	0.2	-13.4	-13.3
40 to 44	93.8	93.3	82.3	-0.5	-11.9	-12.3
45 to 49	91.9	92.8	80.0	0.9	-13.8	-13.0
50 to 54	86.0	86.9	76.9	1.0	-11.5	-10.6

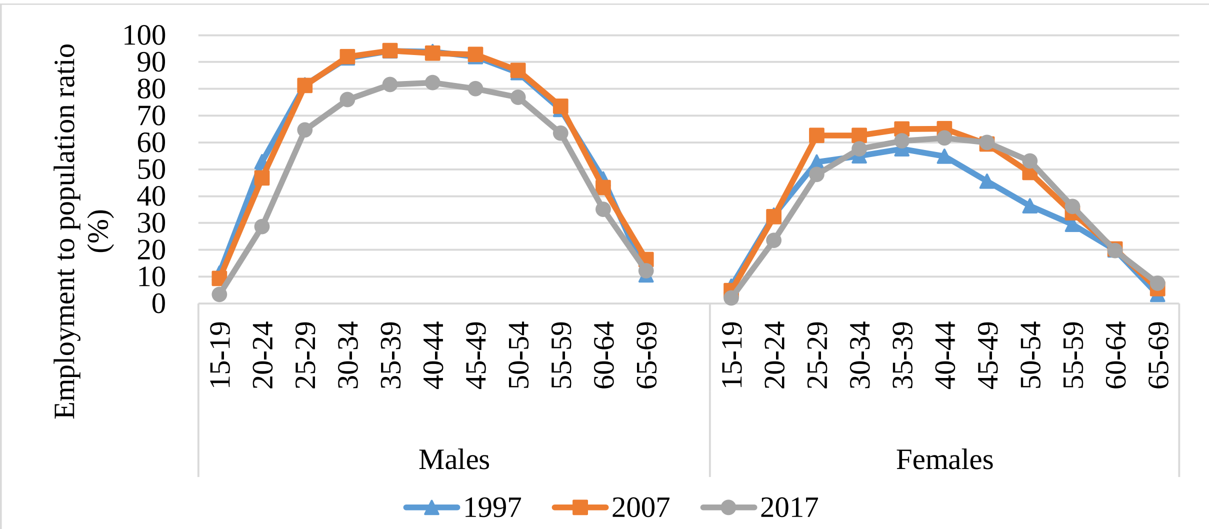
Table 3.20 : Employment to population ratio (%) by gender and age (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Males (continued)						
55 to 59	72.3	73.5	63.4	1.7	-13.8	-12.3
60 to 64	46.4	43.2	35.1	-6.8	-18.8	-24.3
65 to 69	10.6	16.4	12.2	53.6	-25.4	14.7
All Ages	59.0	60.8	49.3	3.1	-18.9	-16.4
Females						
15 to 19	6.4	4.7	2.0	-26.4	-58.1	-69.2
20 to 24	33.0	32.3	23.6	-1.9	-27.2	-28.5
25 to 29	52.7	62.6	48.0	18.8	-23.3	-8.9
30 to 34	55.0	62.6	57.6	13.8	-7.9	4.8
35 to 39	57.6	65.0	60.5	12.9	-6.9	5.2
40 to 44	54.9	65.1	61.7	18.5	-5.2	12.4
45 to 49	45.6	59.5	60.0	30.3	0.9	31.5
50 to 54	36.3	48.8	53.1	34.2	8.8	46.1
55 to 59	29.5	33.7	36.1	14.2	7.2	22.5
60 to 64	19.9	20.2	19.7	1.7	-2.4	-0.8
65 to 69	3.3	5.4	7.5	62.5	38.3	124.9
All Ages	30.8	36.9	33.1	19.6	-10.3	7.3

Source: OECD (OECD, 2020b)

Note: In 1997, the employment to population ratio for people aged 65-69 years is not available. Thus, we used the employment to population ratio for people aged 65+.

Graph 3.1: Employment to population ratio (%) by gender and age



Note: Graphs based on data from ELSTAT (2017)

3.2.9 Present Value of Lifetime Earnings

To estimate the present value of lifetime earnings (PVLE), we used the following data: survival probability, employment-to-population ratio and GDP per worker. Survival probability did not change significantly among years. Thus, changes in PVLE were mainly due to changes in employment-to-population ratio and GDP per worker, both of which were presented in detail above. Additionally, as GDP per worker was the same for both males and females, differences in PVLE between genders were mainly due to differences in the employment-to-population ratio. For both genders, PVLE was increased in 2007 with the increase being higher for females. After a decade, in 2017, PVLE decreased, as both employment-to-population ratio and GDP per worker followed a down-flow trend (Table 3.21).

Table 3.21: Present Value of Lifetime Earnings, constant 2017 euro (million), by gender and age

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Males						
15 to 19	1.900	2.360	1.809	24.2	-23.4	-4.8
20 to 24	1.758	2.192	1.694	24.7	-22.7	-3.7
25 to 29	1.549	1.942	1.516	25.4	-21.9	-2.1
30 to 34	1.304	1.638	1.286	25.6	-21.4	-1.3
35 to 39	1.056	1.328	1.046	25.8	-21.2	-0.9
40 to 44	0.818	1.031	0.810	26.2	-21.5	-0.9
45 to 49	0.594	0.753	0.588	26.8	-22.0	-1.1
50 to 54	0.390	0.496	0.383	27.3	-22.8	-1.7
55 to 59	0.214	0.274	0.206	28.3	-25.1	-3.8
60 to 64	0.082	0.111	0.080	36.2	-28.5	-2.6
65 to 69	0.014	0.026	0.018	90.6	-32.2	29.2
Females						
15 to 19	1.037	1.513	1.305	45.9	-13.7	25.8
20 to 24	0.953	1.400	1.218	47.0	-13.0	27.8
25 to 29	0.823	1.220	1.082	48.2	-11.3	31.5
30 to 34	0.673	1.002	0.910	48.8	-9.2	35.1
35 to 39	0.526	0.792	0.730	50.5	-7.8	38.8
40 to 44	0.385	0.589	0.554	52.9	-5.9	43.9
45 to 49	0.262	0.402	0.387	53.1	-3.6	47.6
50 to 54	0.165	0.243	0.238	47.5	-2.3	44.1
55 to 59	0.089	0.124	0.120	39.3	-2.9	35.2
60 to 64	0.033	0.047	0.047	42.9	0.2	43.2
65 to 69	0.004	0.009	0.011	101.6	25.6	153.3

Note: Own calculations, using data on employment-to-population ratio (OECD.Stat, 2020a), survival probability (WHO, 2018b) and GDP per worker (ELSTAT, 2017; IMF, 2019).

Chapter 4: Estimating the Economic Cost of High BMI and Dietary Risks in Greece

In this chapter, the economic cost of high body-mass index (Section 4.1) and dietary risks[29] (Section 4.2) are estimated, separately, using the cost of illness approach as described in Section 3.1. For both risk factors, direct and indirect costs are presented analytically for year 2017. In Sections 4.1.5 and 4.2.5, the economic costs are also estimated and presented for years 2007 and 1997 for a ten-year and twenty-year comparison.

Previous literature is limited. As regards the economic cost of overweight and obesity, Fry and Finley (2005) estimated it for the EU countries pro rata to the UK data for 1998 derived from Comptroller and Auditor General (2001). Based on their estimations, in 2002, the economic cost of obesity in Greece was €863 million. A more recent OECD study estimated the impact of overweight on health expenditure, labour market productivity (through absenteeism, presenteeism, unemployment and early retirement) and GDP for the period 2020-2050 using the OECD SPHeP-NCDs model (OECD, 2019). Based on their results, on average, 9.1% of healthcare expenditure is estimated to be related to overweight, while the overweight-attributable labour market cost is estimated at USD PPP 176 per capita. Additionally, GDP in Greece is estimated to fall by 3% each year. To the best of our knowledge, no study exists regarding the economic cost of dietary risks.

4.1 The Economic Cost of High BMI in Greece

4.1.1 Direct Cost of High BMI

In 2017, healthcare expenditure related to high BMI was €1,491.89 million or €138.55 per capita, which is equivalent to 0.83% of GDP. Among the three types of cost, direct cost is the highest one, accounting for 41.35% of total cost of high BMI (the sum of direct and indirect cost). The highest percentage of direct cost is public health expenditures (60.83%).

[29] Dietary risks include diets low in fruits, vegetables, whole grains, nuts and seeds, fiber, milk, calcium, omega-3 oils, and polyunsaturated fatty acids; and high in sodium, red meat, processed meat, sweetened beverages, and trans fats.

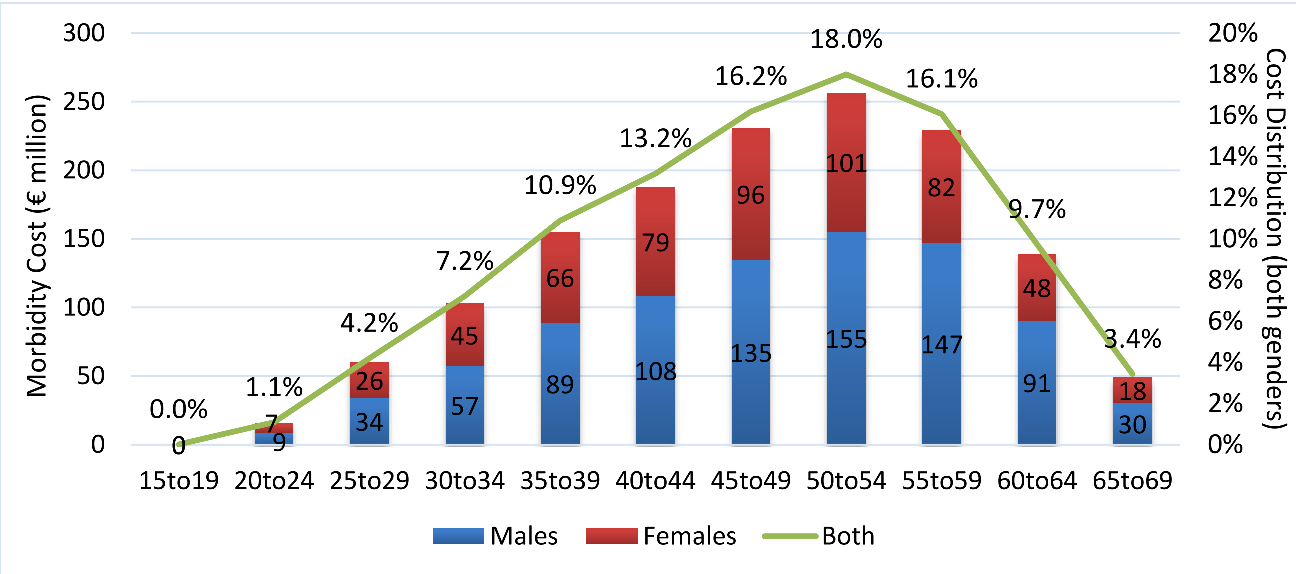
4.1.2 Indirect Cost of High BMI: Morbidity Cost

The morbidity cost of high BMI is €1,424.67 million or €132.30 per capita. This amount is slightly lower than the direct cost and accounts for 0.79% of GDP and 39.48% of the total cost of high BMI (the sum of direct and indirect cost).

Morbidity cost by gender and age is showed in Graph 4.1. The cost distribution by age is left-tailed and depicted by the green line. The cost at the youngest age group (15-19) is extremely low (€104,586.39) compared to the other age groups. Cost increases with age, reaching its highest level at age group 50-54 and then drops. More than half (50.27%) of morbidity cost results from working adults aged 45-59.

The columns, in Graph 4.1, depict morbidity cost by gender (blue for males; red for females) for each age group. About 40% of morbidity cost is caused by females. The rest results from males, ranging from 55.77% for age group 30-34 to 65.31% for age group 60-64.

Graph 4.1: Morbidity Cost Attributable to High BMI by gender and age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Table 4.1 shows the morbidity cost distribution by main causes. All of the morbidity cost is caused by non-communicable diseases. The primary cause is diabetes, accounting for 50.20% (52.39% for males; 46.90% for females) of morbidity cost. The second cause is musculoskeletal disorders (26.42% for both genders; 25.30% for males; 28.10% for females) and the third is cardiovascular diseases (11.63% for both genders; 11.91% for males; 11.21% for females). These three causes are responsible for 88.25% of morbidity cost due to high BMI.

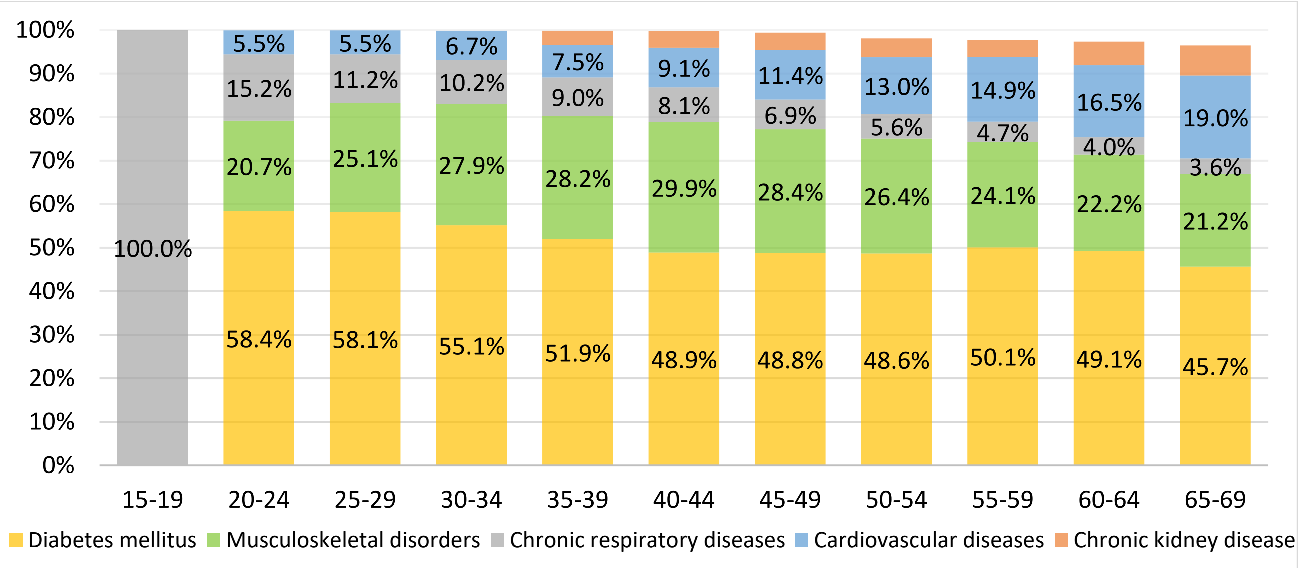
Table 4.1: High BMI Attributable Morbidity Cost distribution by main causes, ages 15-69

	Males	Females	Both
B. Non-communicable diseases	**100.00%**	**100.00%**	**100.00%**
Neoplasms	0.68%	1.13%	0.86%
Cardiovascular diseases	11.91%	11.21%	11.63%
Chronic respiratory diseases	5.76%	8.37%	6.79%
Digestive diseases	0.02%	0.05%	0.03%
Neurological disorders	0.28%	0.27%	0.28%
Diabetes mellitus	52.39%	46.90%	50.20%
Chronic kidney disease	3.55%	3.85%	3.67%
Musculoskeletal disorders	25.30%	28.10%	26.42%
Sense organ diseases	0.11%	0.13%	0.12%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

When we examine the morbidity cost distribution by disease within each age group, the proportion of morbidity cost generated by diabetes is higher at younger ages (ages 20-29). As age increases, the relevant importance of diabetes decreases, with only exception the slightly increase for age group 55-59. As regards cardiovascular diseases, its relevant importance increases with age. On the other hand, the proportion of morbidity cost generated by musculoskeletal disorders increases with age, reaching its higher level at age group 40-44 and then drops again. For the first age group (15-19), the only cause related to high BMI is chronic respiratory diseases (see, Graph 4.2).

Graph 4.2: High BMI Attributable Morbidity Cost distribution by disease within each age group, both genders



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

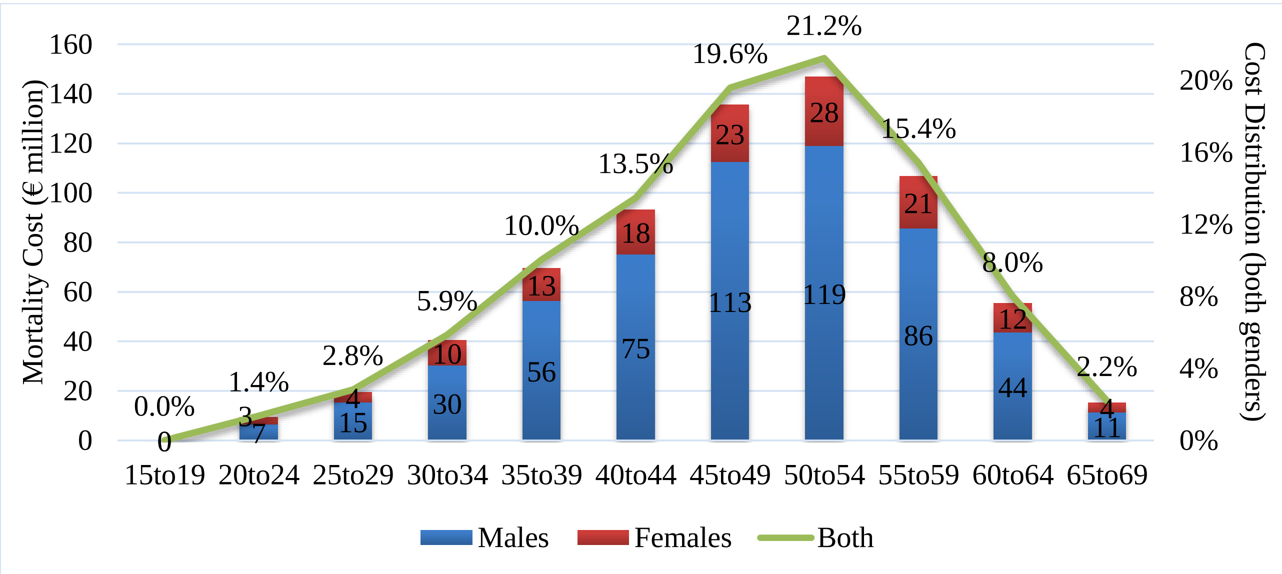
4.1.3 Indirect Cost of High BMI: Mortality Cost

In 2017, the mortality cost of high BMI was €691.75 million or €64.24 per capita, which is equivalent to 0.38% of GDP. Mortality cost accounts for 19.17% of total cost of high BMI (the sum of direct and indirect cost of smoking) and it is the lowest among the three types of cost.

Graph 4.3, below, shows mortality cost related to high BMI, by gender and age. The cost distribution by age, depicted by green line, is left-tailed. The cost for the two youngest age groups (15-19 and 20-24) is low compared to the other age groups. As with morbidity cost, mortality cost reaches its highest level at age group 50-54 and then drops. However, the concentration to middle-aged population is higher compared to morbidity cost. Specifically, 56.25% of mortality cost results from working adults aged 45-59, while the corresponding proportion for morbidity cost is 50.27%.

The columns, in Graph 4.3, depict mortality cost by gender (blue for males; red for females) for each age group. In all age groups but the youngest one, the highest proportion of mortality cost (80.39%) results from males' exposure, ranging from 70.41% at age group 20-24 to 83.06% at age group 45-49. Thus, less than 20% of mortality cost is caused by females.

Graph 4.3: Mortality Cost Attributable to High BMI by gender and age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

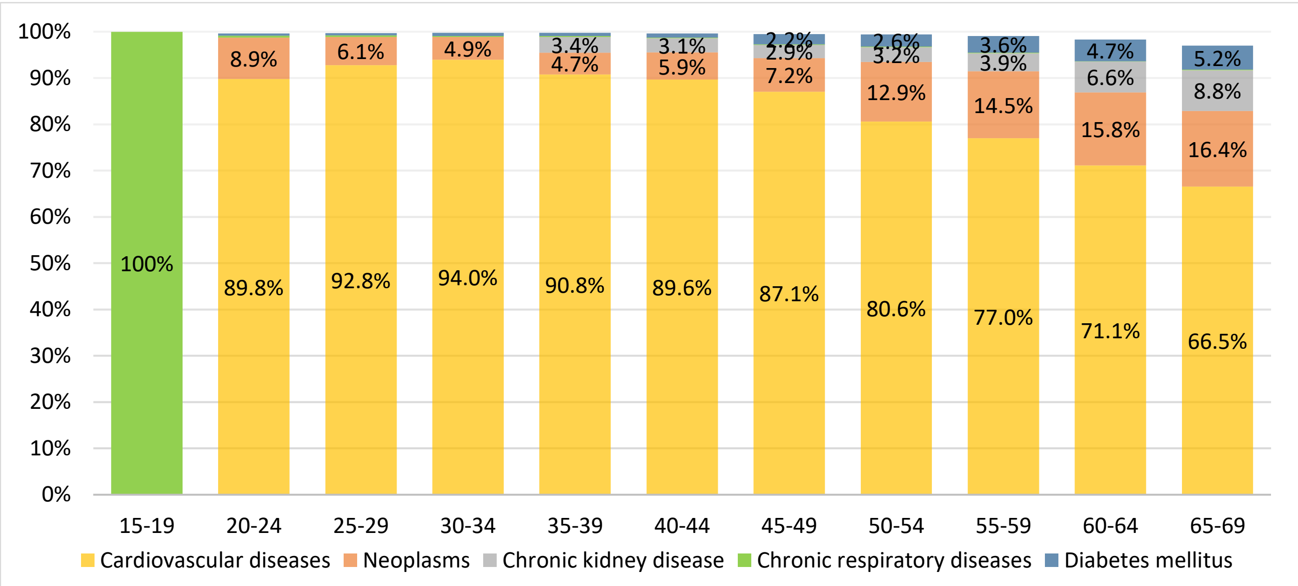
Table 4.2 shows the mortality cost distribution by main causes. Mortality cost is caused only by non-communicable diseases. Specifically, the greatest proportion of mortality cost is caused by cardiovascular diseases (83.72% for both genders; 85.15% for males; 77.83% for females) and mostly by ischemic heart disease. The second cause is neoplasms, accounting for 9.86% (9.09% for males; 12.98% for females) of mortality cost.

Table 4.2: High BMI Attributable Morbidity Cost distribution by main causes, ages 15-69

	Males	Females	Both
B. Non-communicable diseases	**100.00%**	**100.00%**	**100.00%**
Neoplasms	9.09%	12.98%	9.86%
Cardiovascular diseases	85.15%	77.83%	83.72%
Chronic respiratory diseases	0.10%	0.38%	0.16%
Digestive diseases	0.17%	0.52%	0.24%
Neurological disorders	0.33%	0.87%	0.44%
Diabetes mellitus	2.14%	2.87%	2.28%
Chronic kidney disease	3.00%	4.55%	3.31%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Graph 4.4: High BMI Attributable Mortality Cost distribution by disease within each age group, both genders



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Examining the mortality cost distribution by disease within each age group, the only cause of mortality cost for the youngest age group is chronic respiratory diseases. However, the impact of chronic respiratory diseases on mortality cost for the rest age groups is limited (0.11% - 0.43%). Cardiovascular diseases are responsible for 89.8% of mortality cost for ages 20-24. This proportion slightly increases to 94.0% for ages 30-34 while for older ages it steadily drops. The proportions of neoplasms, chronic kidney diseases and diabetes are higher for older ages (see, Graph 4.4).

4.1.4 Summarizing the Results on the Economic Cost of high BMI

Table 4.3 presents the total cost of high BMI. The direct cost is €1,491.89 million and the indirect cost is €2,116.42 million (morbidity cost is €1,424.67 million and mortality cost is €691.75 million). Thus, the total cost of high BMI, which is the sum of direct and indirect costs, is €3,608.31 million. This amount is equivalent to €335.09 per capita. As a percentage of GDP, the total cost of high BMI is 2.00%.

Table 4.3: Total cost of high BMI (the sum of direct and indirect cost)

	Total Cost of High BMI			
	€ (million)	**per capita €**	**% of GDP**	**% of total cost of high BMI**
Direct cost	1,491.89	138.55	0.83%	41.35%
Indirect cost	2,116.42	196.54	1.17%	58.65%
Morbidity cost	1,424.67	132.30	0.79%	39.48%
Mortality cost	691.75	64.24	0.38%	19.17%
Total Cost	3,608.31	335.09	2.00%	100.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

4.1.5 Economic Cost of high BMI: a Ten-year and Twenty-year Comparison

The total economic cost of high BMI was €3,160.86 million in 1997, €5,366.71 million in 2007 and €3,608.31 million in 2017. Thus, it rose by 69.79% in 2007 and then, in 2017, fell by 32.76%. Despite the reduction, in 2017 the total cost remained higher than the one in 1997 (by 14.16%). Specifically, both direct and indirect costs increased by 9.52% and 17.66%, respectively. However, as regards indirect costs, we observe an increase in morbidity cost (37.34%) but an decrease in mortality cost (9.14%). In all three years, direct cost was higher than morbidity and mortality cost, especially in 2007 when it rose by 84.45% and accounted for 46.82% of total cost.

As shown in Table 4.4, per capita costs follow the same pattern with costs. The total cost per capita was €297.37 in 1997 and rose to €486.29, a 63.53% increase. Then, in 2017, it decreased by 31.09%

reaching €335.09. this is equivalent to a 3.71% reduction since 1997. As regards total cost as percentage of GDP, it was 1.92% in 1997, increased to 2.22% in 2007 and then fell to 2.00% in 2017. The difference with costs and per capita costs was that morbidity cost showed a steady increase. Also, direct cost, in 2017, was not higher but exact to 1997 levels (0.83% of GDP).

Table 4.4: Comparison of economic cost of high BMI in 1997, 2007 and 2017

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Cost in 2017 constant million €						
Direct Cost	1,362.15	2,512.48	1,491.89	84.45%	-40.62%	9.52%
Indirect Cost	1,798.70	2,854.23	2,116.42	58.68%	-25.85%	17.66%
Morbidity Cost	1,037.35	1,717.01	1,424.67	65.52%	-17.03%	37.34%
Mortality Cost	761.35	1,137.22	691.75	49.37%	-39.17%	-9.14%
Total Cost	3,160.86	5,366.71	3,608.31	69.79%	-32.76%	14.16%
Per capita cost in 2017 constant €						
Direct Cost	128.15	227.66	138.55	77.65%	-39.14%	8.12%
Indirect Cost	169.22	258.63	196.54	52.84%	-24.01%	16.14%
Morbidity Cost	97.59	155.58	132.30	59.42%	-14.96%	35.57%
Mortality Cost	71.63	103.05	64.24	43.86%	-37.66%	-10.32%
Total Cost	297.37	486.29	335.09	63.53%	-31.09%	12.68%
Cost as % of GDP						
Direct Cost	0.83%	1.04%	0.83%	25.30%	-20.19%	0.00%
Indirect Cost	1.09%	1.18%	1.17%	8.26%	-0.85%	7.34%
Morbidity Cost	0.63%	0.71%	0.79%	12.70%	11.27%	25.40%
Mortality Cost	0.46%	0.47%	0.38%	2.17%	-19.15%	-17.39%
Total Cost	1.92%	2.22%	2.00%	15.63%	-9.91%	4.17%
Cost as % of total cost of high BMI						
Direct Cost	43.09%	46.82%	41.35%	8.66%	-11.68%	-4.04%
Indirect Cost	56.91%	53.18%	58.65%	-6.55%	10.29%	3.06%
Morbidity Cost	32.82%	31.99%	39.48%	-2.53%	23.41%	20.29%
Mortality Cost	24.09%	21.19%	19.17%	-12.04%	-9.53%	-20.42%
Total Cost	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

4.2 The Economic Cost of Dietary Risks in Greece

4.2.1 Direct Cost of Dietary Risks

Healthcare expenditure related to dietary risks was €2,768.80 million in 2017. This amount is equivalent to €257.13 per capita or 1.54% of GDP. The 60.83% of direct cost is public health expenditures. Direct cost accounts for 60.89% of total cost of dietary risks and, thus, it is higher than morbidity and mortality costs.

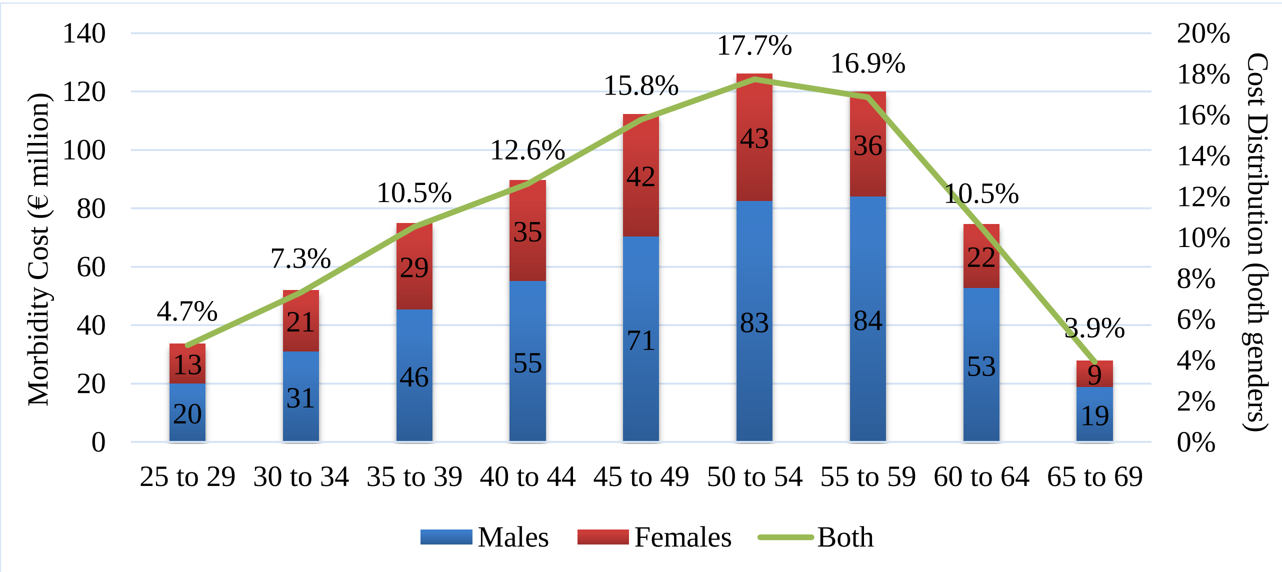
4.2.2 Indirect Cost of Dietary Risks: Morbidity Cost

The morbidity cost related to dietary risks is €711.00 million or €66.03 per capita. As a percentage of GDP, morbidity cost is 0.39%. Among the three types of costs, morbidity cost is the lowest one, accounting for 15.63% of total cost of dietary risks (the sum of direct and indirect costs).

Graph 4.5, below, show morbidity cost by gender and age. The columns, depict morbidity cost by gender (blue for males; red for females) for each age group. For all age groups, the proportion of morbidity costs resulting from females is lower than males. Totally, 35.14% of morbidity cost is caused by females. The rest results from males, ranging from 59.85% at age group 30-34 to 70.81% at age group 60-64.

The cost distribution by age is depicted by the green bell-shaped line in Graph 4.5. Cost reaches its highest level at age group 50-54 and then drops. The highest proportion (63.01%) of morbidity cost results from working adults aged 40-59.

Graph 4.5: Morbidity Cost Attributable to Dietary Risks by gender and age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Table 4.5 shows the morbidity cost distribution by main causes. The main cause categories are few compared to the other risks factors and all belong to non-communicable diseases. However, there are many sub-categories of neoplasms and cardiovascular diseases.

The primary cause of morbidity cost related to dietary risks is diabetes, accounting for 68.04% (68.74% for males; 66.74% for females) of morbidity cost. The second cause is cardiovascular diseases (38.27% for males; 41.39% for females; 40.21% for both genders). These two causes are responsible for almost all morbidity cost due to dietary risks. Both neoplasms and chronic kidney disease account about 1% of morbidity cost.

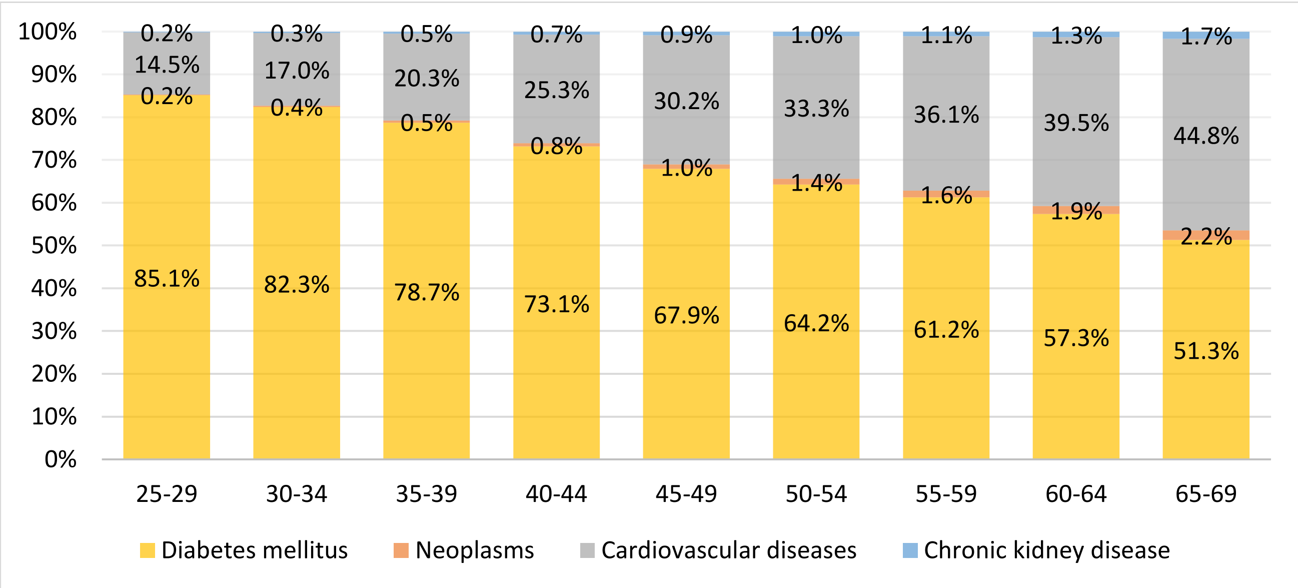
Table 4.5: Dietary Risks Attributable Morbidity Cost distribution by main causes, ages 25-69

	Males	Females	Both
B. Non-communicable diseases	**100.00%**	**100.00%**	**100.00%**
Neoplasms	1.22%	1.02%	1.15%
Cardiovascular diseases	29.10%	31.46%	29.93%
Diabetes mellitus	68.74%	66.74%	68.04%
Chronic kidney disease	0.94%	0.78%	0.88%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

When we examine the morbidity cost distribution by disease within each age group, the proportion of morbidity cost generated by diabetes is higher at younger ages. As age increases, the relevant importance of diabetes decreases and increases mostly that of chronic respiratory diseases (see, Graph 4.6). This pattern is followed by both genders.

Graph 4.6: Dietary Risks Attributable Morbidity Cost distribution by disease within each age group, both genders



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

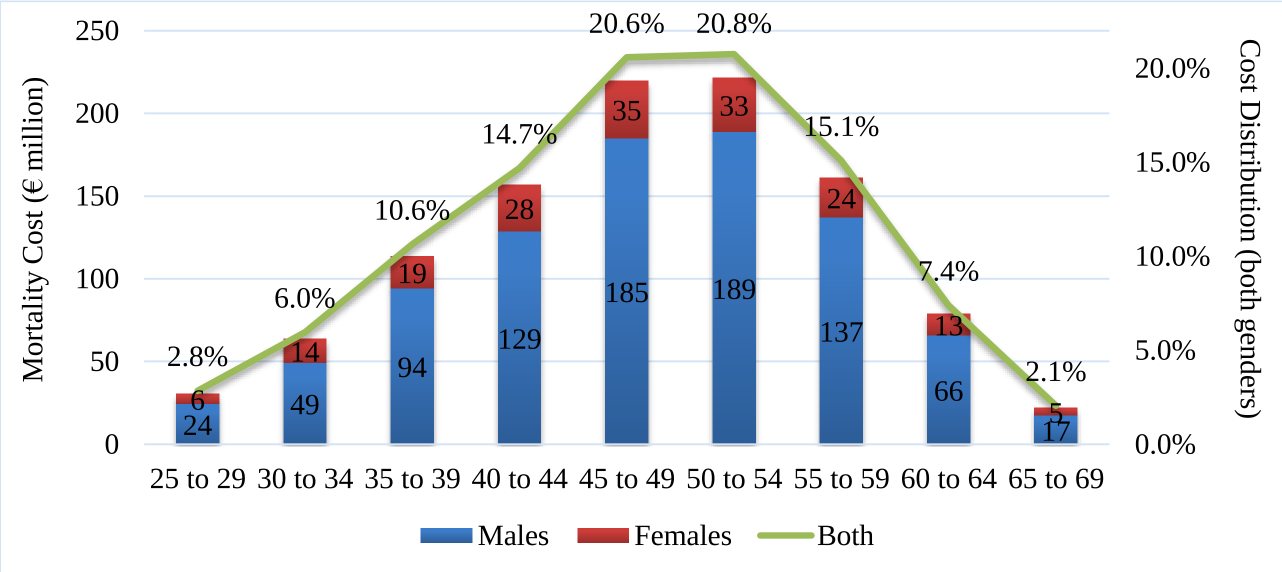
4.2.3 Indirect Cost of Dietary Risks: Mortality Cost

In 2017, the 23.48% of total cost of dietary risks (the sum of direct and indirect cost) was mortality cost which is equal to €1,067.74 million. This amount is equivalent to €99.16 per capita or 0.59% of GDP.

Mortality cost by gender and age is shown in Graph 4.7. The cost distribution by age is depicted by the green bell-shaped line. As with morbidity cost, mortality cost reaches its highest level at age group 50-54 and then drops. However, the concentration in middle-aged population is higher compared to morbidity cost. Specifically,71.11% of morbidity cost results from working adults aged 40-59.

The columns, in Graph 4.7, depict mortality cost by gender (blue for males; red for females) for each age group. In all age groups, the highest proportion of mortality cost results from males' exposure, ranging from 77.60% at age group 30-34 to 85.21% at age group 50-54. Thus, only 16.54% of mortality cost is caused by females.

Graph 4.7: Mortality Cost Attributable to Dietary Risks by gender and age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Table 4.6 shows the morbidity cost distribution by main causes. As occurs with morbidity cost, the main cause categories are few compared to the other risks factors. Almost all of mortality cost is caused by cardiovascular diseases (92.27% for males; 87.36% for females; 91.46% for both genders) while the second cause is neoplasms (6.53% for males; 10.98% for females; 7.27% for both genders). The cost caused by diabetes and chronic kidney diseases is relatively low (see, Table 4.6).

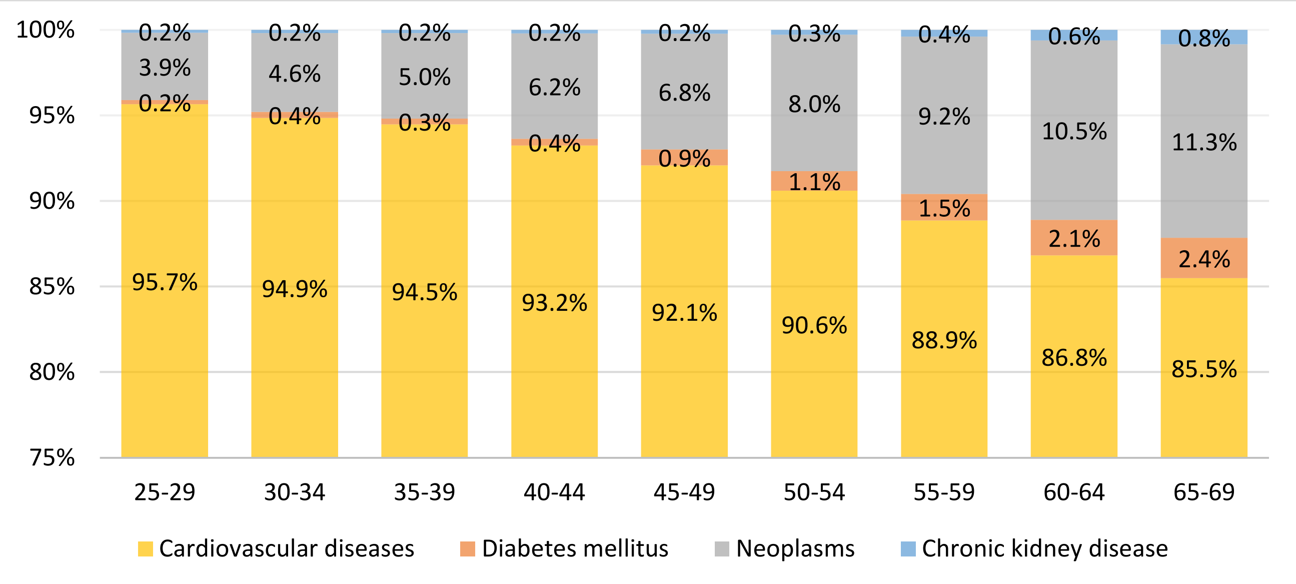
Table 4.6: Dietary Risks Attributable Mortality Cost distribution by main causes, ages 25-69

	Males	Females	Both
B. Non-communicable diseases	**100.00%**	**100.00%**	**100.00%**
Neoplasms	6.53%	10.98%	7.27%
Cardiovascular diseases	92.27%	87.36%	91.46%
Diabetes mellitus	0.92%	1.32%	0.98%
Chronic kidney disease	0.28%	0.35%	0.29%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Examining the mortality cost distribution by disease within each age group, the proportion of mortality cost generated by cardiovascular diseases is higher for people aged 25-29 years. As age increases, the relevant importance of cardiovascular diseases decreases and that of neoplasms increases (see, Graph 4.8).

Graph 4.8: Dietary Risks Attributable Mortality Cost distribution by disease within each age group, both genders



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

4.2.4 Summarizing the Results on the Economic Cost of Dietary Risks

Summarizing the results for dietary risks, the total cost is €4,547.54 million or €422.31 per capita. From this amount, €2,768,80 million is the direct cost and €1,778.74 million is the indirect cost (morbidity cost is €711.00 million and mortality cost is €1,067.74 million). As a percentage of GDP, the total cost of dietary risks is 2.52% (see, Table 4.7).

Table 4.7: Total cost of Dietary Risks (the sum of direct and indirect cost)

	Total Cost of Dietary Risks			
	€ (million)	per capita €	% of GDP	% of total cost of dietary risks
Direct cost	2,768.80	257.13	1.54%	60.89%
Indirect cost	1,778.74	165.18	0.99%	39.11%
Morbidity cost	711.00	66.03	0.39%	15.63%
Mortality cost	1,067.74	99.16	0.59%	23.48%
Total Cost	4,547.54	422.31	2.52%	100.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

4.2.5 Economic Cost of Dietary Risks: a Ten-year and Twenty-year Comparison

The total economic cost of dietary risks was €4,444.72 million in 1997, €6,789.81 million in 2007 and €4,547.54 million in 2017. Thus, it rose by 52.76% in 2007 but then, in 2017, fell by 33.02%. However, in 2017, the total cost was still slightly higher than the corresponding in 1997 (by 2.31%). Specifically, both direct and indirect costs increased by 1.96% and 2.86%, respectively. The increase in indirect costs was due to the rise in morbidity cost (by 39.77%) as mortality cost fell (by 12.52%). In all three years, direct cost was much higher than morbidity and mortality cost, especially in 2007, as it rose by 60.24% and accounted for 64.09% of total cost (Table 4.8).

Per capita costs follow the same pattern with costs. In 1997, the total cost per capita was €418.16 and in 2007 increased by 47.13%, reaching €615.24. In 2017, it decreased to levels close to those in 1997 (€422.31). As regards total cost as percentage of GDP, in 1997, it was 2.71% of GDP. After a decade, in 2007, direct cost increased while the opposite occurred in indirect costs. Because the absolute percentage change in direct cost was higher than the absolute percentage change in indirect costs, the total cost of dietary risks increased, reaching 2.81% of GDP. In 2017, both direct and indirect costs decreased and the total cost was 2.52% of GDP, lower than the corresponding in 1997. Morbidity cost as percentage of GDP was the only type of cost that showed a steady increase while the opposite occurred in mortality cost (Table 4.8).

Table 4.8: Comparison of economic cost of dietary risks in 1997, 2007 and 2017

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Cost in 2017 constant million €						
Direct Cost	2,715.47	4,351.38	2,768.80	60.24%	-36.37%	1.96%
Indirect Cost	1,729.25	2,438.43	1,778.74	41.01%	-27.05%	2.86%
Morbidity Cost	508.69	778.58	711.00	53.06%	-8.68%	39.77%
Mortality Cost	1,220.57	1,659.85	1,067.74	35.99%	-35.67%	-12.52%
Total Cost	4,444.72	6,789.81	4,547.54	52.76%	-33.02%	2.31%
Per capita cost in 2017 constant €						
Direct Cost	255.47	394.29	257.13	54.34%	-34.79%	0.65%
Indirect Cost	162.69	220.95	165.18	35.81%	-25.24%	1.53%
Morbidity Cost	47.86	70.55	66.03	47.42%	-6.41%	37.97%
Mortality Cost	114.83	150.40	99.16	30.98%	-34.07%	-13.65%
Total Cost	418.16	615.24	422.31	47.13%	-31.36%	0.99%
Cost as % of GDP						
Direct Cost	1.65%	1.80%	1.54%	9.07%	-14.78%	-7.05%
Indirect Cost	1.05%	1.01%	0.99%	-4.02%	-2.30%	-6.23%
Morbidity Cost	0.31%	0.32%	0.39%	4.17%	22.31%	27.41%
Mortality Cost	0.74%	0.69%	0.59%	-7.44%	-13.84%	-20.26%
Total Cost	2.71%	2.81%	2.52%	3.97%	-10.30%	-6.73%
Cost as % of total cost of dietary risks						
Direct Cost	61.09%	64.09%	60.89%	4.90%	-5.00%	-0.34%
Indirect Cost	38.91%	35.91%	39.11%	-7.69%	8.91%	0.54%
Morbidity Cost	11.44%	11.47%	15.63%	0.19%	36.35%	36.61%
Mortality Cost	27.46%	24.45%	23.48%	-10.98%	-3.95%	-14.50%
Total Cost	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

4.3 Sensitivity Analysis: a 3% Discount Rate on Mortality Cost

Mortality cost was estimated assuming a 0% discount rate, as it has been argued that human life should not be discounted. However, we estimated mortality cost also at a discount rate of 3%, a standard practice in health economics. Results show that, mortality cost, and thus total cost, is lower when it is assumed a discount rate of 3%. Specifically, the reduction in mortality cost is about 19.14% for both high BMI and dietary risks. That has as a result, total cost being lower by 3.67% for high BMI and 4.48% for dietary risks (see, Table 4.9).

Table 4.9: Comparison of economic cost of selected risk factors with 0% & 3% discount rate in 2017

		r=0%	**r=3%**	**Difference (%)**
High BMI	**Mortality Cost (€ million)**	559.37	691.75	-19.14%
	Total Cost (€ million)	3,475.93	3,608.31	-3.67%
	(% of GDP)	(1.93%)	(2.00%)	
Dietary Risks	**Mortality Cost (€ million)**	863.84	1,067.74	-19.10%
	Total Cost (€ million)	4,343.64	4,547.54	-4.48%
	(% of GDP)	(2.41%)	(2.52%)	

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Chapter 5: Estimating the Economic Cost of Tobacco Smoking and Secondhand Smoke Exposure in Greece[30]

The main motivation behind this thesis had to do with the dietary risks and the high body-mass index which is related to poor eating habits. But we found it interesting, as well as useful, to estimate also the economic cost of tobacco use, another sin good with high consumption in Greece and great impact on public health . The rising trends in tobacco use, however, have been reversed due to a number of tobacco control policies that have been proposed and implemented worldwide. These policies can serve as a guide in the fight against obesity and related diseases.

Research on the economic cost of tobacco use in Greece is limited. Tsalapati et al. (2014) estimated the hospital costs for the treatment of smoking-attributable diseases and found them to be €554 million in 2011. In Tsalapati et al. (2014), which focuses on the calculation of the direct cost of active smoking, the annual cost approach (prevalence-based) was used and smoking attributable fractions for each disease were calculated using estimated relative risks of mortality from the American Cancer Society's Prevention Study (Centers for Disease Control and Prevention, 2009). Goodchild et al. (2018) and Jarvis et al. (2012, 2009) estimated both the direct and indirect costs of active smoking but none focuses exclusively on Greece. Goodchild et al. (2018), in a study on global economic cost of smoking, found that the cost in Greece was €4.7 billion, equivalent to 2.4% of GDP in 2012. The same study also showed that the total global economic cost of smoking was 1.8% of global GDP with the cost being higher in high-income countries, the Americas and Europe. In Europe, the cost was 2.5% of the regional GDP, varying from 3.6% of GDP in Eastern Europe to 2% in the rest of Europe. On the other hand, Jarvis et al. (2012, 2009), a study commissioned by the DG SANCO for the EU, estimated it at €6.2 billion in 2000 and €11.2 billion in 2009, corresponding to 4.5% of GDP. Results differ mainly due to differences in mortality cost estimation. Jarvis et al. (2012, 2009) used the willingness-to-pay approach while Goodchild et al. (2018) employed the human capital approach, with the former producing much higher estimates. Neither study estimates the economic cost of SHS, which is expected to be relatively high for Greece. Jarvis et al. (2012, 2009) estimated only part of the direct cost of SHS, that of public healthcare spending.

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[30] A shorter version of this chapter is published in Tobacco Prevention & Cessation. doi: 10.18332/tpc/113091

In this chapter, the economic cost of tobacco use is estimated separately for tobacco smoking and SHS exposure and results are presented in Sections 5.1 and 5.2, respectively. Summarized results for the economic cost of tobacco use are shown in Section 5.3. Estimates are for 2019 and obtained using the data described in Section 3.2 and the cost of illness approach as presented in Section 3.1. In Sections 5.1.5 and 5.2.5, the economic costs are also estimated and presented for years 2007 and 1997, making a ten-year and twenty-year comparison.

5.1 The Economic Cost of Tobacco Smoking in Greece

5.1.1 Direct Cost of Smoking

In 2017, the smoking-attributable healthcare expenditure (SAE) was €2,940.65 million or €273.09 per capita, which is the highest amount among the three types of cost. Direct cost accounts for 1.63% of GDP and 44.86% of total cost of smoking (the sum of direct and indirect cost). The highest percentage of direct cost is public health expenditures (60.83%).

5.1.2 Indirect Cost of Smoking: Morbidity Cost

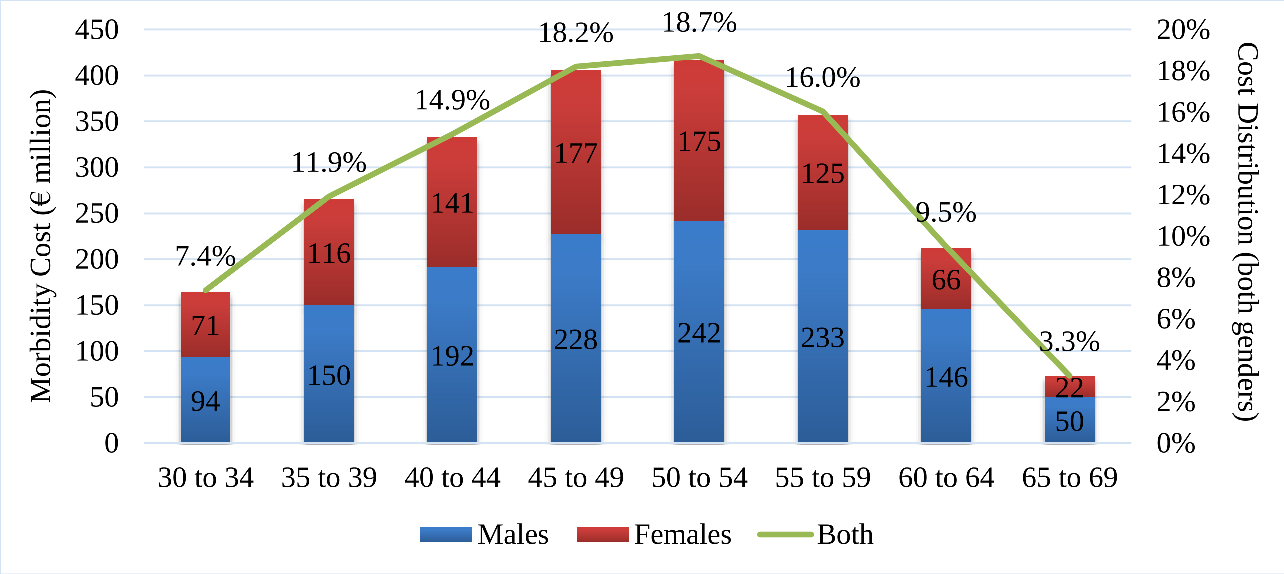
The morbidity cost of smoking was €2,227.34 million which is equivalent to €206.84 per capita. This amount is 1.24% of GDP and 33.98% of total cost of smoking (the sum of direct and indirect cost of smoking).

Graph 5.1, below, shows morbidity cost by gender and age. The cost distribution by age is depicted by the green bell-shaped line. Cost reaches its highest level at age group 50-54 and then drops. The highest proportion (67.90%) of smoking attributable morbidity cost results from working adults aged 40-59. The columns, in Graph 5.1, depict morbidity cost by gender (blue for males; red for females) for each age group. For all age groups, the highest proportion of smoking attributable morbidity costs results from males, ranging from 56.29% at age group 45-49 to 69.08% at age group 65-69. Totally, almost 40% of smoking attributable morbidity costs is caused by females.

Table 5.1 shows the morbidity cost distribution by main causes. Almost all of the morbidity cost (98.56%) is caused by non-communicable diseases. The main cause is musculoskeletal disorders (mainly low back pain) accounting for 56.95% (53.66% for males; 61.89% for females) of morbidity cost. The second cause is chronic respiratory diseases (20.66% for both genders; 21.48% for males;

19.44% for females) and the third is diabetes (9.67% for both genders; 11.34% for males; 7.17% for females).

Graph 5.1: Smoking Attributable Morbidity Cost by gender & age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

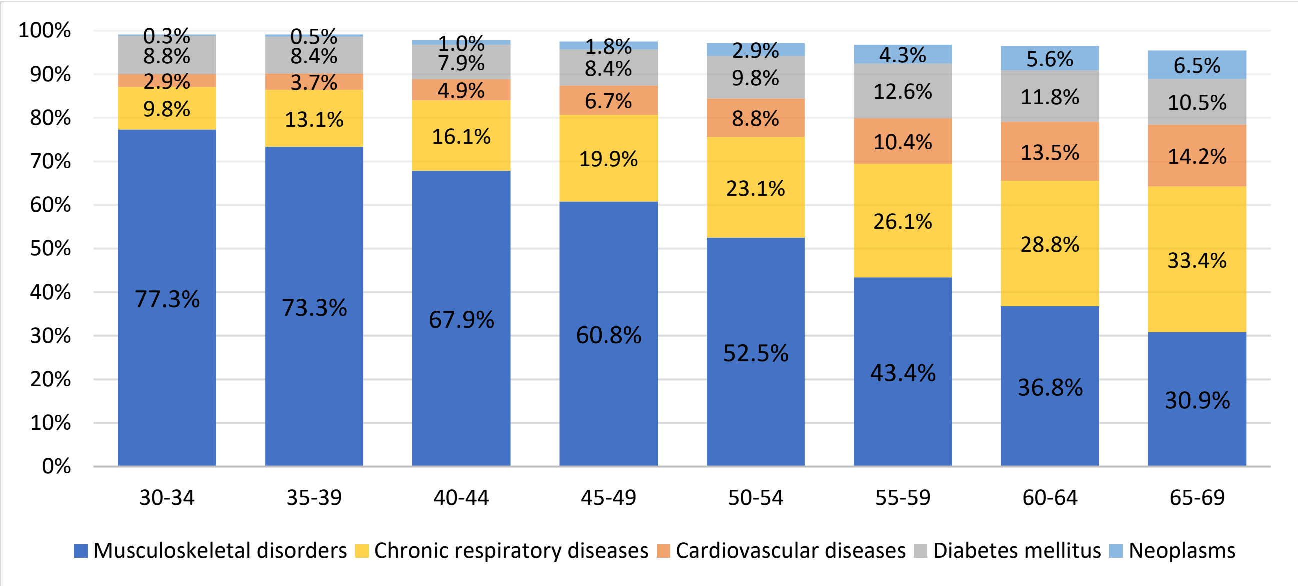
Table 5.1: Smoking Attributable Morbidity Cost distribution by main causes, ages 30-69

	Males	**Females**	**Both**
A. Communicable, maternal, neonatal, and nutritional diseases	**0.10%**	**0.06%**	**0.08%**
Respiratory infections and tuberculosis	0.10%	0.06%	0.08%
B. Non-communicable diseases	**98.67%**	**98.39%**	**98.56%**
Neoplasms	3.03%	1.84%	2.55%
Cardiovascular diseases	8.18%	6.93%	7.68%
Chronic respiratory diseases	21.48%	19.44%	20.66%
Digestive diseases	0.23%	0.21%	0.22%
Neurological disorders	0.49%	0.68%	0.57%
Diabetes mellitus	11.34%	7.17%	9.67%
Musculoskeletal disorders	53.66%	61.89%	56.95%
Sense organ diseases	0.26%	0.24%	0.25%
C. Injuries	**1.23%**	**1.55%**	**1.36%**
Transport injuries	0.35%	0.36%	0.35%
Unintentional injuries	0.87%	1.19%	1.00%
Self-harm and interpersonal violence	0.01%	0.01%	0.01%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

When we examine the morbidity cost distribution by disease within each age group, the proportion of morbidity cost generated by musculoskeletal disorders is higher at younger ages. As age increases, the relevant importance of musculoskeletal disorders decreases and increases mostly that of chronic respiratory diseases (see, Graph 5.2). This pattern is followed by both genders.

Graph 5.2: SAMbC distribution by disease within each age group, both genders



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

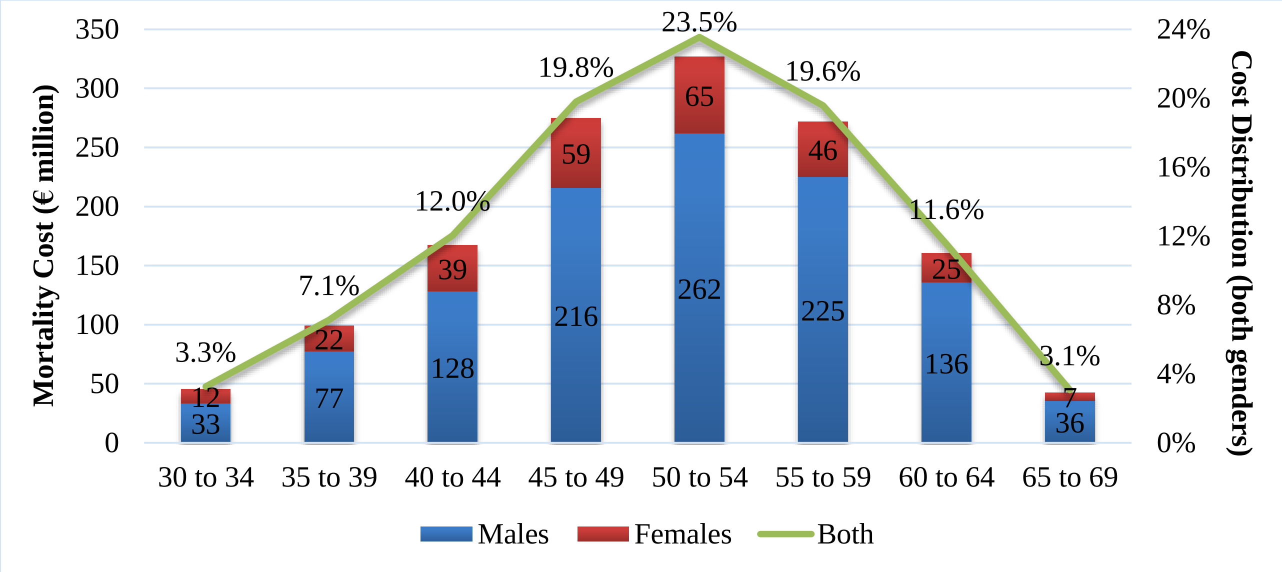
5.1.3 Indirect Cost of Smoking: Mortality Cost

The mortality cost of smoking was €1,387.30 million, which is equivalent to €128.83 per capita. This amount is 0.77% of GDP and 21.16% of total cost of smoking (the sum of direct and indirect cost of smoking). Among the three types of cost, mortality cost is the lowest.

Graph 5.3 shows the mortality cost by gender and age. The cost distribution by age is the green bell-shaped line. The cost reaches its highest level at age group 50-54 and then drops. The pick of mortality cost is observed in the same age group as morbidity cost. The highest proportion (62.93%) of smoking attributable mortality cost is due to working adults aged 45-59.

The columns, in Graph 5.3, depict the mortality cost by gender for each age group. For all age groups, the highest proportion of smoking attributable mortality costs results from males, ranging from 73.91% at age group 30-34 to 84.66% at age group 60-64. Totally, almost 20% of smoking attributable mortality costs is caused by females, which is about the half of the corresponding proportion of morbidity costs.

Graph 5.3: Smoking Attributable Mortality Cost (SAMtC) by gender & age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Table 5.2: Smoking Attributable Mortality Cost distribution by main causes, ages 30-69

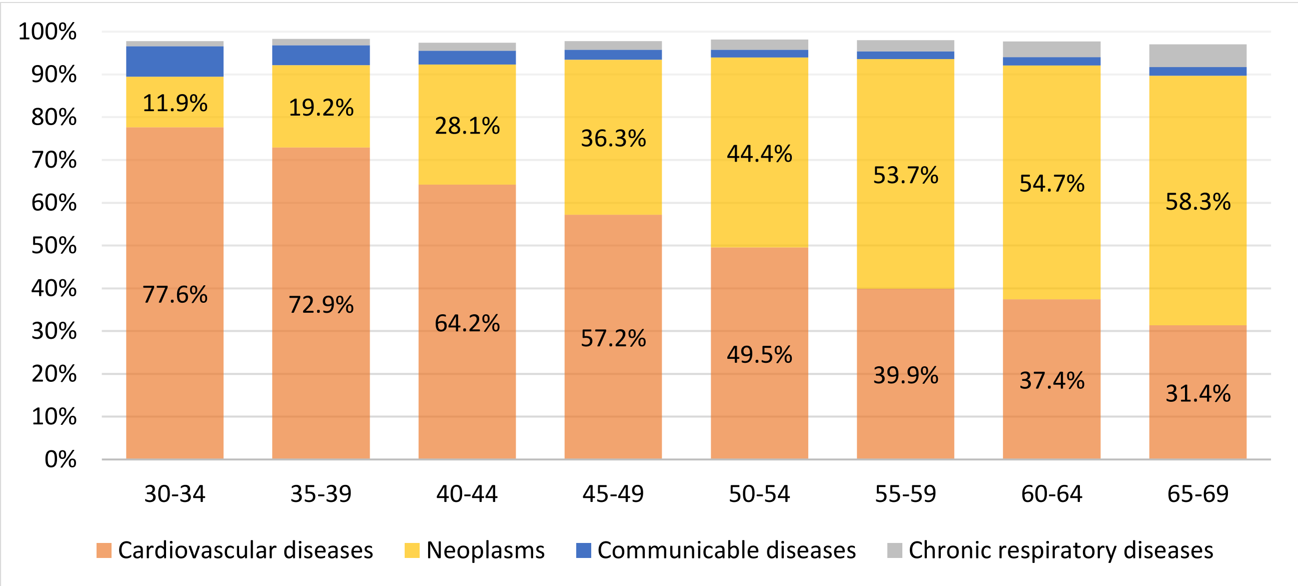
	Males	Females	Both
A. Communicable, maternal, neonatal, and nutritional diseases	**2.39%**	**2.86%**	**2.48%**
Respiratory infections and tuberculosis	2.39%	2.86%	2.48%
B. Non-communicable diseases	**97.27%**	**96.88%**	**97.19%**
Neoplasms	39.97%	47.26%	41.41%
Cardiovascular diseases	53.42%	43.95%	51.55%
Chronic respiratory diseases	2.29%	3.07%	2.45%
Digestive diseases	0.55%	0.48%	0.54%
Neurological disorders	0.62%	1.70%	0.83%
Diabetes mellitus	0.40%	0.38%	0.39%
Musculoskeletal disorders	0.01%	0.03%	0.01%
C. Injuries	**0.34%**	**0.26%**	**0.33%**
Transport injuries	0.26%	0.18%	0.24%
Unintentional injuries	0.08%	0.08%	0.08%
Self-harm and interpersonal violence	0.00%	0.00%	0.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Table 5.2, above, shows the mortality cost distribution by main causes. The highest proportion (97.19%) of mortality cost is caused by non-communicable diseases. The primary cause among males is cardiovascular diseases (mainly ischemic heart disease) accounting for 53.42% of mortality cost, following by neoplasms (39.97%). For females, the ranking of two main causes is the reverse but the proportions are close. Specifically, the main cause among females is neoplasms (47.26%) and the second cause is cardiovascular diseases (43.95%).

When we examine the mortality cost distribution by disease within each age group, the proportion of mortality cost generated by cardiovascular diseases is higher at younger ages. As age increases, the relevant importance of cardiovascular diseases decreases and increases mostly that of neoplasms (Graph 5.4). This pattern is slightly different for females as the relevant importance of cardiovascular diseases increases at age group 60-64 and then drops again, but these variations are not important (from 36.14% at age group 55-59 increases to 38.44% at age group 60-64 and then drops to 36.61% at age group 65-69).

Graph 5.4: SAMtC distribution by disease within each age group, both genders



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.1.4 Summarizing the Results on the Economic Cost of Smoking

Table 5.3 presents the total cost of smoking which consists of direct and indirect cost. The direct cost is €2,940.65 million and the indirect cost is €3,614.64 million (morbidity cost is €2,227.34 million and mortality cost is €1,387.30 million). Thus, the total cost of smoking (the sum of direct and indirect cost) is €6,555.30 million, which is equivalent to €608.76 per capita. As a percentage of GDP, the total cost of smoking is 3.64%.

Table 5.3: Total cost of smoking (sum of direct and indirect cost)

	Total Cost of Smoking			
	€ (million)	per capita €	% of GDP	% of total cost of smoking
Direct cost	2,940.65	273.09	1.63%	44.86%
Indirect cost	3,614.64	335.68	2.01%	55.14%
Morbidity cost	2,227.34	206.84	1.24%	33.98%
Mortality cost	1,387.30	128.83	0.77%	21.16%
Total Cost	6,555.30	608.76	3.64%	100.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.1.5 Economic Cost of Smoking: a Ten-year and Twenty-year Comparison

The total economic cost of smoking was €6,719.70 million in 1997 and €9,917.95 million in 2007. Thus, compared to 1997, the total economic cost of smoking rose by 47.60% in 2007 but fell by 2.45% in 2017. In 2007, among the three types of costs (direct cost, morbidity cost and mortality cost), direct cost bore the highest increase (60.95%) and accounted for about half (49.82%) of total cost of smoking. In 2017, the total cost was close to 1997 levels. Specifically, both direct and indirect costs were slightly lower than those in 1997. However, as regards indirect costs, an increase in morbidity cost (11.56%) and a decrease in mortality cost (16.08%) are observed (see, Table 5.4).

Table 5.4: Comparison of economic cost of smoking in 1997, 2007 and 2017

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Cost in 2017 constant million €						
Direct Cost	3,070.07	4,941.37	2,940.65	60.95%	-40.49%	-4.22%
Indirect Cost	3,649.63	4,976.58	3,614.64	36.36%	-27.37%	-0.96%
Morbidity Cost	1,996.55	2,802.64	2,227.34	40.37%	-20.53%	11.56%
Mortality Cost	1,653.08	2,173.94	1,387.30	31.51%	-36.18%	-16.08%
Total Cost	6,719.70	9,917.95	6,555.30	47.60%	-33.90%	-2.45%
Per capita cost in 2017 constant €						
Direct Cost	288.83	447.75	273.09	55.02%	-39.01%	-5.45%
Indirect Cost	343.36	450.94	335.68	31.33%	-25.56%	-2.24%
Morbidity Cost	187.84	253.95	206.84	35.20%	-18.55%	10.12%
Mortality Cost	155.52	196.99	128.83	26.66%	-34.60%	-17.16%
Total Cost	632.19	898.69	608.76	42.16%	-32.26%	-3.71%

Table 5.4: Comparison of economic cost of smoking in 1997, 2007 and 2017 (continued)

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Cost as % of GDP						
Direct Cost	1.87%	2.05%	1.63%	9.55%	-20.30%	-12.68%
Indirect Cost	2.22%	2.06%	2.01%	-7.19%	-2.72%	-9.72%
Morbidity Cost	1.22%	1.16%	1.24%	-4.46%	6.44%	1.70%
Mortality Cost	1.01%	0.90%	0.77%	-10.49%	-14.53%	-23.50%
Total Cost	4.09%	4.11%	3.64%	0.46%	-11.48%	-11.07%
Cost as % of total cost of smoking						
Direct Cost	45.69%	49.82%	44.86%	9.05%	-9.96%	-1.81%
Indirect Cost	54.31%	50.18%	55.14%	-7.61%	9.89%	1.53%
Morbidity Cost	29.71%	28.26%	33.98%	-4.89%	20.24%	14.36%
Mortality Cost	24.60%	21.92%	21.16%	-10.90%	-3.45%	-13.97%
Total Cost	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

The total cost per capita was €632.19 in 1997 and increased by 42.16% in 2007 reaching €898.69. However, in 2017 it decreased to €608.76, a 3.71% reduction since 1997. As shown in Table 5.4, per capita costs follow the same trend with costs but the same does not occur with costs as percentage of GDP. In 1997, total cost was 4.09% of GDP while after a decade it slightly increased reaching 4.11% of GDP. This increase was due to direct costs as indirect costs as percentage of GDP decreased from 2.22% in 1997 to 2.06% in 2007. In 2017, total cost was 3.64% of GDP, significantly lower than the corresponding in 1997.

5.2 The Economic Cost of Secondhand Smoke Exposure in Greece

5.2.1 Direct Cost of Secondhand Smoke Exposure

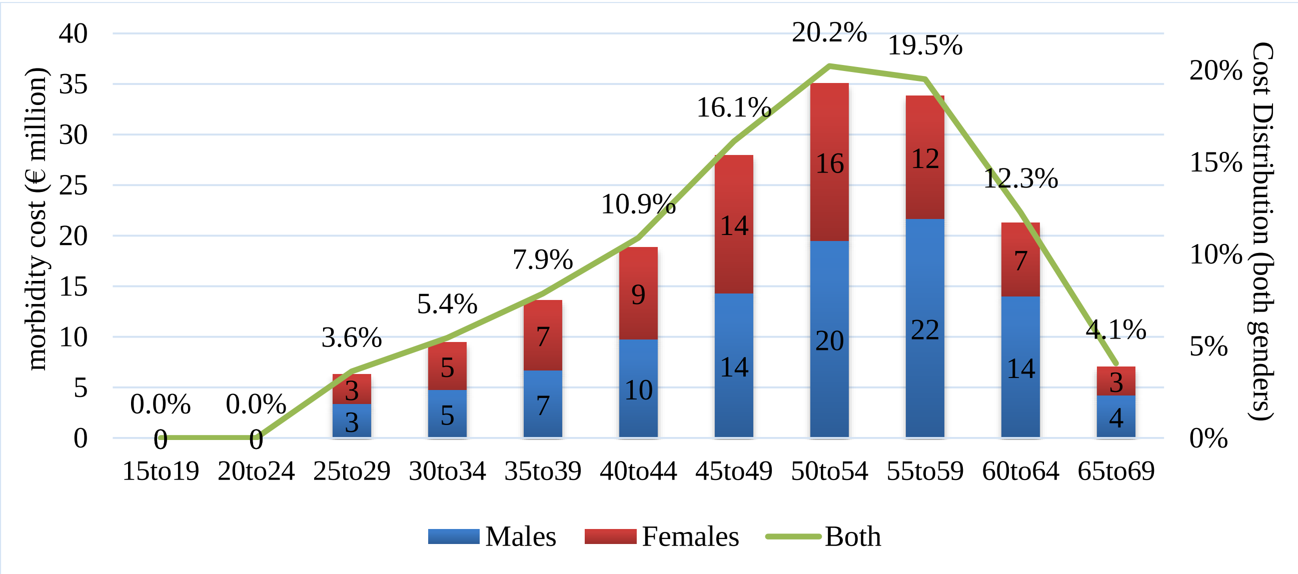
Healthcare expenditure related to SHS is €324.45 million which is equivalent to €30.13 per capita. Direct cost of SHS is the highest among the three types of cost and accounts for 0.18% of GDP and 49.64% of total cost of SHS (the sum of direct and indirect cost). The 60.83% of direct cost is public health expenditures.

5.2.2 Indirect Cost of Secondhand Smoke Exposure: Morbidity Cost

The morbidity cost of SHS is €173.43 million or €16.11 per capita. This amount represents 0.10% of GDP and 26.53% of total cost of SHS (the sum of direct and indirect cost of SHS).

Graph 5.5, below, shows morbidity cost attributed to SHS by gender and age. The cost distribution by age is left-tailed and depicted by the green line. The cost at the two youngest age groups (15-19 and 20-24) is extremely low (€342.27 and € 3,275.89) compared to the other age groups. Cost reaches its highest level at age group 50-54 and then drops. The highest proportion (55.86%) of morbidity cost results from working adults aged 45-59. The columns, in Graph 5.5, depict morbidity cost by gender (blue for males; red for females) for each age group. Except of age group 35-39, in all other age groups the highest proportion of morbidity cost results from males, ranging from 50.56% at age group 30-34 to 66.95% at age group 15-19. Totally, 43.29% of morbidity cost related to SHS is caused by females, a proportion higher than that related to smoking.

Graph 5.5: Morbidity Cost Attributed to SHS by gender & age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Table 5.5 shows the morbidity cost distribution by main causes. The primary cause of morbidity cost attributable to SHS is diabetes (55.95% for males; 50.48% for females; 52.90% for both genders) and the second cause is chronic respiratory diseases (38.27% for males; 41.39% for females; 40.21% for both genders). These two causes are responsible for almost all morbidity cost due to SHS.

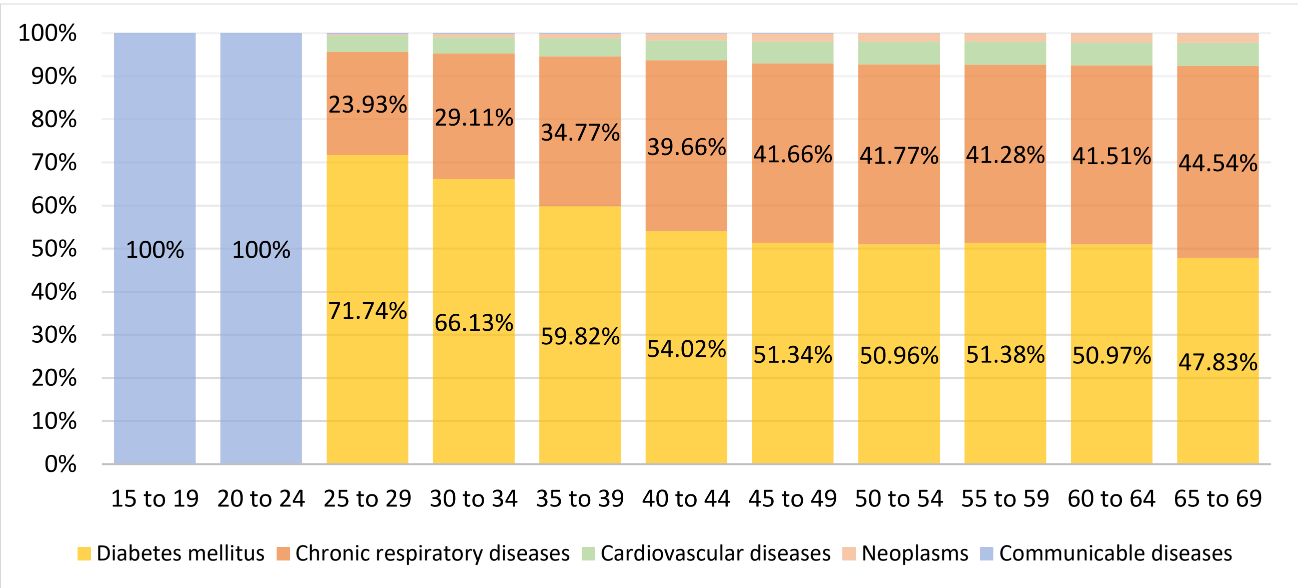
Table 5.5: SHS Attributable Morbidity Cost distribution by main causes, ages 30-69

	Males	Females	Both
A. Communicable, maternal, neonatal, and nutritional diseases	**0.11%**	**0.10%**	**0.09%**
Respiratory infections and tuberculosis	0.11%	0.10%	0.09%
B. Non-communicable diseases	**99.89%**	**99.90%**	**99.91%**
Neoplasms	1.00%	2.66%	1.77%
Cardiovascular diseases	4.67%	5.37%	5.02%
Chronic respiratory diseases	38.27%	41.39%	40.21%
Diabetes mellitus	55.95%	50.48%	52.90%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

When we examine the morbidity cost distribution by disease within each age group, the proportion of morbidity cost generated by diabetes is higher at younger ages (ages 25 and over). As age increases, the relevant importance of diabetes decreases and increases that of chronic respiratory diseases. In this pattern, a stability for age groups 45-49 to 60-64 is observed. As regards the first two age groups (15-19 and 20-24), the only cause related to SHS is lower respiratory infection which is a communicable disease (see, Graph 5.6).

Graph 5.6: SHS Attributable Morbidity Cost distribution by disease within each age group, both genders



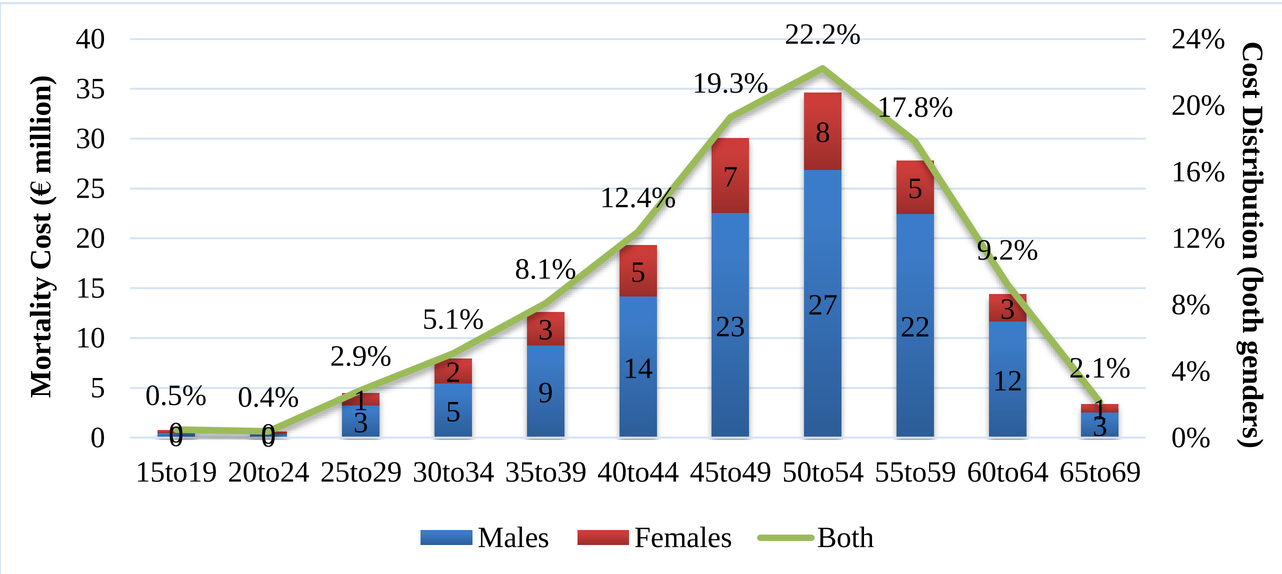
Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.2.3 Indirect Cost of Secondhand Smoke Exposure: Mortality Cost

The mortality cost of SHS is €155.75 million which is equivalent to €14.46 per capita. This cost is 0.09% of GDP and 23.83% of total cost of SHS. Among the three types of cost, mortality cost is the lowest one.

Graph 5.7, below, shows mortality cost related to SHS by gender and age. The cost distribution by age is left-tailed and depicted by the green line. The cost at the two youngest age groups (15-19 and 20-24) is low compared to the other age groups but their contribution is higher than the corresponding to morbidity cost. Cost reaches its highest level at age group 50-54 and then drops. The highest proportion (59.35%) of morbidity cost results from working adults aged 45-59. The columns, in Graph 5.7, depict mortality cost by gender (blue for males; red for females) for each age group. In all age groups the highest proportion of mortality cost results from males' exposure, ranging from 65.03% at age group 15-19 to 81.14% at age group 60-64. As it occurs with morbidity cost, when we compare females' contribution to mortality cost of smoking and SHS, the proportion of mortality cost due to SHS is higher than that related to smoking (23.43% and 19.72%, respectively).

Graph 5.7: Mortality Cost Attributable to Second-hand Smoke by gender and age



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

The main cause of mortality cost attributable to SHS is cardiovascular diseases (69.24% for males; 53.32% for females; 66.09% for both genders) and the second cause is neoplasms (20.21% for males; 31.27% for females; 23.57% for both genders). These two causes are responsible for 89.66% of mortality cost due to SHS (see, Table 5.6).

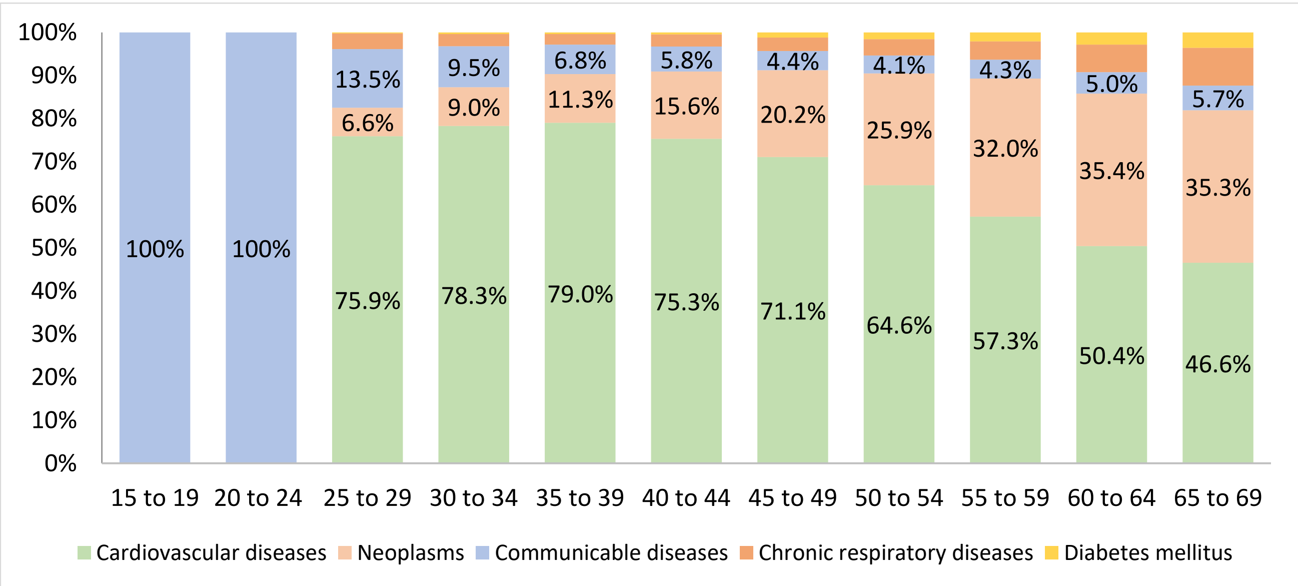
Table 5.6: SHS Attributable Mortality Cost distribution by main causes, ages 15-69

	Males	Females	Both
A. Communicable, maternal, neonatal, and nutritional diseases	**5.90%**	**8.57%**	**5.07%**
Respiratory infections and tuberculosis	5.90%	8.57%	5.07%
B. Non-communicable diseases	**94.10%**	**91.43%**	**94.93%**
Neoplasms	20.21%	31.27%	23.57%
Cardiovascular diseases	69.24%	53.32%	66.09%
Chronic respiratory diseases	3.33%	5.19%	3.82%
Diabetes mellitus	1.32%	1.65%	1.45%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Examining the mortality cost distribution by disease within each age group, the proportion of mortality cost generated by cardiovascular diseases is higher for people aged 25-39 years. Then, as age increases, the relevant importance of cardiovascular diseases decreases and that of neoplasms increases. For ages 15-24, mortality cost is caused by lower respiratory infection which is a communicable disease (see, Graph 5.8).

Graph 5.8: SHS Attributable Mortality Cost distribution by disease within each age group, both genders



Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.2.4 Summarizing the Results on the Economic Cost of Secondhand Smoke Exposure

Table 5.7 presents the total cost of SHS. The direct cost is €324.45 million and the indirect cost is €329.18 million (morbidity cost is €173.43 million and mortality cost is €155.75 million). Thus, the total cost of SHS is €653.63 million, which is equivalent to €60.70 per capita. As a percentage of GDP, the total cost of SHS is 0.36%.

Table 5.7: Total cost of SHS (the sum of direct and indirect cost)

	Total Cost of SHS			
	€ (million)	**per capita €**	**% of GDP**	**% of total cost of SHS**
Direct cost	324.45	30.13	0.18%	49.64%
Indirect cost	329.18	30.57	0.18%	50.36%
Morbidity cost	173.43	16.11	0.10%	26.53%
Mortality cost	155.75	14.46	0.09%	23.83%
Total Cost	653.63	60.70	0.36%	100.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.2.5 Economic Cost of Secondhand Smoke Exposure: a Ten-year and Twenty-year Comparison

The total economic cost of SHS was €699.08 million in 1997 and €1,041.70 million in 2007. Thus, compared to 1997, the total cost of SHS increased by 49.01% in 2007 but decreased by 6.50% in 2017. In 2007, direct cost bore the highest increase (57.88%) among the three types of costs (direct cost, morbidity cost and mortality cost) and accounted for more than half (55.72%) of total cost of SHS. In 2017, both direct and indirect costs were lower than those in 1997. However, as regards indirect costs, a rise in morbidity cost (28.55%) and a fall in mortality cost (20.74%) are observed (see, Table 5.8).

The total cost per capita was €65.77 in 1997 and increased to €94.39 in 2007 (a 43.52% increase). However, in 2017, it decreased by 7.71% compared to 1997. As shown in Table 5.8, per capita costs follow the same trend with costs but the same does not occur with costs as percentage of GDP. In 2007, total cost as percentage of GDP increased slightly. As a result, in both 1997 and 2007, the rounded total cost was 0.43% of GDP. This increase was due to direct costs, since indirect costs as percentage of GDP decreased from 0.20% in 1997 to 0.19% in 2007. In 2017, total cost as percentage of GDP fell to 0.36%.

Table 5.8: Comparison of economic cost of SHS exposure in 1997, 2007 and 2017

	1997	**2007**	**2017**	**% change 1997-2007**	**% change 2007-2017**	**% change 1997-2017**
Cost in 2017 constant million €						
Direct Cost	367.67	580.48	324.45	57.88%	-44.11%	-11.75%
Indirect Cost	331.42	461.23	329.18	39.17%	-28.63%	-0.67%
Morbidity Cost	134.92	206.80	173.43	53.28%	-16.13%	28.55%
Mortality Cost	196.50	254.43	155.75	29.48%	-38.79%	-20.74%
Total Cost	699.08	1,041.70	653.63	49.01%	-37.25%	-6.50%
Per capita cost in 2017 constant €						
Direct Cost	34.59	52.60	30.13	52.06%	-42.72%	-12.89%
Indirect Cost	31.18	41.79	30.57	34.04%	-26.85%	-1.96%
Morbidity Cost	12.69	18.74	16.11	47.63%	-14.05%	26.89%
Mortality Cost	18.49	23.05	14.46	24.71%	-37.26%	-21.76%
Total Cost	65.77	94.39	60.70	43.52%	-35.69%	-7.71%
Cost as % of GDP						
Direct Cost	0.22%	0.24%	0.18%	7.46%	-25.14%	-19.56%
Indirect Cost	0.20%	0.19%	0.18%	-5.28%	-4.41%	-9.46%
Morbidity Cost	0.08%	0.09%	0.10%	4.33%	12.32%	17.18%
Mortality Cost	0.12%	0.11%	0.09%	-11.87%	-18.02%	-27.75%
Total Cost	0.43%	0.43%	0.36%	1.42%	-15.96%	-14.77%
Cost as % of total cost of SHS exposure						
Direct Cost	52.59%	55.72%	49.64%	5.95%	-10.92%	-5.62%
Indirect Cost	47.41%	44.28%	50.36%	-6.60%	13.74%	6.23%
Morbidity Cost	19.30%	19.85%	26.53%	2.86%	33.66%	37.49%
Mortality Cost	28.11%	24.42%	23.83%	-13.11%	-2.44%	-15.23%
Total Cost	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.3 Economic Cost of Tobacco Use

In 2017, the economic cost of tobacco use[31] in Greece is €6,939.24 million or €644.42 per capita, which is equivalent to 3.85% of GDP. However, if we sum the economic cost of smoking and SHS, the total cost is €7,208.93. From this amount, €6,555.30 million is attributable to smoking and the rest, €653.63 million, is related to second-hand smoke. Thus, 9.07% of total cost is attributable to secondhand smoke (see Table 5.9). The economic cost of smoking and SHS is 3.89% higher than the economic cost of tobacco use. This happens because when we estimate the economic cost of tobacco use, we take into

[31] Tobacco use includes tobacco smoking, SHS exposure and chewing tobacco. The use of chewing tobacco in Greece is extremely low. This is the reason we do not estimate the economic cost of chewing tobacco separately.

account the joint consequences of exposure to more than one of tobacco subcategories (smoking, SHS exposure and chewing tobacco).

Table 5.9: Economic Cost of Tobacco use

	Direct Cost € (million)	Indirect Cost € (million)		Total Cost		
		Morbidity Cost	Mortality Cost	€ (million)	Per Capita €	% of GDP
Tobacco	3,147.64	2,334.96	1,456.65	6,939.24	644.42	3.85%
Smoking & SHS	3,265.11	2,400.78	1,543.05	7,208.93	669.47	4.00%
Smoking	2,940.65	2,227.34	1,387.30	6,555.30	608.76	3.64%
SHS	324.45	173.43	155.75	653.63	60.70	0.36%
SHS % of total	9.94%	7.22%	10.09%	9.07%	9.07%	9.07%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.3.1 Economic Cost of Tobacco Use: a Ten-year and Twenty-year Comparison

The highest proportion of the cost of tobacco use comes from smoking. Therefore, changes over time in the cost of tobacco use will be mainly affected by changes in smoking-related costs. Indeed, comparing ten-year and twenty-year changes in costs of smoking and tobacco use (see Table 5.4 and Table 5.10), it is clear that they follow the same trend.

In 1997, the total economic cost of tobacco use was €7,095.50 million or €667.54 per capita. After a decade, it rose to €10,513.89 million (€952.69 per capita), a 48.18% (42.72%) increase. However, in 2017, total cost of tobacco use fell again to €6,939.24 million (€644.42 per capita). That year, both direct and indirect costs were close to 1997 levels but an increase in morbidity cost (12.51%) and an decrease in mortality cost (15.83%) are observed (see, Table 5.10).

In 1997, total cost of tobacco use was 4.32% of GDP. After a decade, direct cost increased while the opposite occurred in indirect costs. Because the absolute percentage change in direct cost was higher than the absolute percentage change in indirect costs, the total cost of tobacco use increased, reaching 4.36% of GDP. In 2017, both direct and indirect costs decreased and the total cost counted 3.85% of GDP.

Table 5.10: Comparison of economic cost of tobacco use in 1997, 2007 and 2017

	1997	2007	2017	% change 1997-2007	% change 2007-2017	% change 1997-2017
Cost in 2017 constant million €						
Direct Cost	3,289.47	5,304.42	3,147.64	61.25%	-40.66%	-4.31%
Indirect Cost	3,806.03	5,209.47	3,791.61	36.87%	-27.22%	-0.38%
Morbidity Cost	2,075.41	2,928.17	2,334.96	41.09%	-20.26%	12.51%
Mortality Cost	1,730.62	2,281.30	1,456.65	31.82%	-36.15%	-15.83%
Total Cost	7,095.50	10,513.89	6,939.24	48.18%	-34.00%	-2.20%
Per capita cost in 2017 constant €						
Direct Cost	309.47	480.65	292.31	55.31%	-39.18%	-5.55%
Indirect Cost	358.07	472.04	352.11	31.83%	-25.41%	-1.66%
Morbidity Cost	195.25	265.33	216.84	35.89%	-18.28%	11.05%
Mortality Cost	162.82	206.71	135.27	26.96%	-34.56%	-16.92%
Total Cost	667.54	952.69	644.42	42.72%	-32.36%	-3.46%
Cost as % of GDP						
Direct Cost	2.00%	2.20%	1.75%	9.75%	-20.52%	-12.77%
Indirect Cost	2.32%	2.16%	2.10%	-6.84%	-2.52%	-9.19%
Morbidity Cost	1.26%	1.21%	1.30%	-3.97%	6.80%	2.56%
Mortality Cost	1.05%	0.95%	0.81%	-10.28%	-14.48%	-23.27%
Total Cost	4.32%	4.36%	3.85%	0.85%	-11.60%	-10.85%
Cost as % of total cost of tobacco use						
Direct Cost	46.36%	50.45%	45.36%	8.83%	-10.09%	-2.16%
Indirect Cost	53.64%	49.55%	54.64%	-7.63%	10.28%	1.86%
Morbidity Cost	29.25%	27.85%	33.65%	-4.78%	20.82%	15.04%
Mortality Cost	24.39%	21.70%	20.99%	-11.04%	-3.26%	-13.94%
Total Cost	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

5.4 Sensitivity Analysis: a 3% Discount Rate on Mortality Cost

In previous Chapter, mortality cost of dietary risks and high BMI was estimated also assuming a 3% discount rate, instead of zero discounting. Following the same procedure, results show that with discounting, mortality cost is lower. Smoking-related mortality cost was 16.44% lower. The reduction on mortality cost was similar for tobacco use (16.61%) but higher for SHS exposure. As expected, total cost decreased too with the change being -3.5% for smoking and tobacco use and -4.35% for SHS exposure (see, Table 5.11).

Table 5.11: Comparison of economic cost of selected risk factors with 0% & 3% discount rate in 2017

		r=0%	r=3%	Difference (%)
Smoking	**Mortality Cost (€ million)**	1,159.26	1,387.30	-16.44%
	Total Cost (€ million)	6,327.26	6,555.30	-3.48%
	(% of GDP)	(3.51%)	(3.64%)	
SHS	**Mortality Cost (€ million)**	127.32	155.75	-18.25%
	Total Cost (€ million)	625.21	653.63	-4.35%
	(% of GDP)	(0.35%)	(0.36%)	
Tobacco use	**Mortality Cost (€ million)**	1,214.73	1,456.65	-16.61%
	Total Cost (€ million)	6,697.33	6,939.24	-3.49%
	(% of GDP)	(3.72%)	(3.85%)	

Note: Calculations based on IHME, ELSTAT, EUROSTAT, OECD & IMF data.

Chapter 6: Discussion and Conclusions of Part B

Part B presents a systematic and detailed estimation of the economic cost of selected risk factors which are of high concern in Greece. These risks factors are tobacco use, including tobacco smoking and SHS exposure, high BMI (i.e., overweight and obesity) and dietary risks[32]. Tobacco use is the major problem as it is the leading risk factor for deaths and disability, with YLD and death rates higher than the corresponding average for the European region, high income countries and globally. On the other hand, prevalence of overweight and obese is significantly high and presents an increasing trend. One of the strongest determinants of high BMI is poor diet. YLD and death rates related to high BMI and dietary risks are both higher than the global average.

The total economic cost of tobacco use is estimated at €6.9 billion (€644.4 per capita or 3.85% of GDP) in 2017. Of this amount, the highest proportion is related to tobacco smoking. Specifically, estimating separately the economic cost of tobacco smoking and SHS exposure, it results to an amount of €6.6 billion (€608.8 per capita or 3.64% of GDP) and €653.6 million (€60.7 per capita or 0.36% of GDP), respectively.

Second in the ranking is the economic cost of dietary risks amounting to €4.6 billion (€422.3 per capita or 2.52% of GDP), followed by the economic cost of high BMI which is €3.6 billion (€335.1 per capita or 2.00% of GDP). The direct cost ranged from 41.35% (high BMI) to 60.89% (dietary risks) of total cost. Dietary risks was the only risk factor for which direct cost was higher than indirect costs and, between indirect costs, mortality cost was higher than morbidity cost. The higher mortality cost is the one which could explain the high direct cost of dietary risks as the SAFs used are based on the same data. Compared to the alternative approaches (friction cost method and willingness to pay approach), the value of estimated indirect cost lies in between (Goodchild et al., 2018).

The analysis of indirect cost by gender showed that the highest proportion of indirect cost was related to males. Females bore only 16.5% (dietary risks) to 23.4% (SHS exposure) of mortality cost. This could be explained by females' lower burden on number of deaths related to each risk factor (from

[32] Dietary risks include diets low in fruits, vegetables, whole grains, nuts and seeds, fiber, milk, calcium, omega-3 oils, and polyunsaturated fatty acids; and high in sodium, red meat, processed meat, sweetened beverages, and trans fats.

25.3%[33] for smoking to 31.0% for SHS exposure) and lower employment-to-population ratios compared with males. Also, despite the fact that females' number of YLDs related to each risk factor is about or more than half of total YLDs (from 43.8% for dietary risks to 52.1% for SHS exposure), females bore only 35.1% (dietary risks) to 43.3% (SHS exposure) of morbidity cost. This can also be explained by the females' lower employment-to-population ratio.

As regards the indirect cost by age group, both morbidity and mortality costs increased with age, up to the age group 50-54 years, and then decreased (the cost distribution by age group is a bell-shaped curve with a peak at age group 50-54). 50.3% (high BMI) to 55.9% (SHS exposure) of morbidity cost and 56.2% (high BMI) to 62.9%(smoking) of mortality cost was borne by people aged 45-59 years. The higher indirect cost at middle age groups resulted from the high employment-to-population ratios and the relatively high number of YLDs and deaths. For younger ages, both YLDs and deaths were lower than older age groups while, for people aged 60-69, employment-to-population ratios were low and only a small increase or decrease in the number of YLDs is observed.

The leading cause of death for all risk factors was cardiovascular diseases. Results showed that 51.55% (tobacco smoking) to 91.46% (dietary risks) of mortality cost was due to cardiovascular diseases. On the other hand, the main cause of disability was musculoskeletal disorders for smoking, amounting to 56.95% of morbidity cost. For the rest risk factors, the main cause was diabetes accounting for 50.20% (high BMI) to 68.04% (dietary risks) of morbidity cost. When we estimated the morbidity and mortality cost of high BMI, the cost related to females' breast cancer was negative for age groups 20-49 because the number of deaths and YLDs were negative. This happened because high BMI, as all risk factors, reduces life expectancy and that as a result reduces the amount of time available to develop a disease or condition, such as breast cancer (OECD, 2019). Moreover, based on the most consistent studies on pre-menopause, obesity has an inverse relationship with the incidence of breast cancer (Dal Bello et al., 2018). It may also help to mention that SAFs might be high for some diseases but their contribution to the economic cost might be low, if the number of deaths or years lost due to disability are relatively low compared to other diseases. Such an example is larynx cancer, where 86.7% of deaths of males aged 30–69 years is related to tobacco smoking but the corresponding deaths for this group from larynx cancer is only 0.92% of all deaths.

[33] That is, for the population of our interest, 25.3% of total deaths are females.

For a ten- and twenty-year comparison, we also estimated the economic cost of risk factors in 1997 and 2007. For all risk factors, the total economic cost increased in the first decade (1997-2007) but decreased in the second decade (2007-2017). The increase ranges from 47.60% (smoking) to 69.79% (high BMI) and the decrease from 32.76% (high BMI) to 37.25% (SHS exposure). Results differ among risk factors in a twenty-year comparison (1997-2017). Compared to 1997, in 2017 the total economic cost of smoking, SHS exposure and tobacco use decreased by 2.45%, 6.50% and 2.20%, respectively. On the other hand, the total economic cost of high BMI increased by 14.16%. The same occur with the economic cost of dietary risks (a 2.31% increase). However, when this was presented as a percentage of GDP, it fell from 2.71% of GDP in 1997 to 2.52% of GDP in 2017. This happens because the percentage increase of GDP is higher than the percentage increase of cost.[34]

Over the years, changes in the economic cost of a risk factor are due to changes in deaths and YLDs related to that risk factor. When the number of YLDs/deaths attributable to a risk factor decreases, it does not necessarily mean that people have reduced their exposure to the risk factor and, consequently, the likelihood of becoming ill or dying from that risk factor. Instead, it might be the case that PAF increases but YLDs/deaths decrease and thus YLDs/deaths related to the risk factor fall too (e.g. deaths related to high BMI for females aged 30-39 and males aged 20-44). Also the economic cost of risks factors is affected by the country's socio-economic situation through GDP per worker and employment to population ratio. For the same number of YLDs and deaths, a better-performed economy with higher GDP per worker and employment to population ratio would have a relatively higher cost than a worse-performed economy.

Direct cost is affected by changes in PAFs and healthcare expenditures. In 2007, direct cost of all risks factors increased due to the high increase (73%) of healthcare expenditures. In 2017, both PAFs and healthcare expenditures were reduced but healthcare expenditures were still higher (14.7%) than those in 1997. Thus, for those dietary risks whose PAFs were reduced less than 14.7% (high BMI and dietary risks), direct cost in 2017 increased compared to 1997.

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[34] Cost and cost as a percentage of GDP move in opposite direction also in the following cases: direct, indirect and mortality cost of dietary risks (1997-2017 change); indirect, morbidity and mortality cost of smoking and tobacco (1997-2007 change); indirect and mortality cost of SHS exposure and dietary risks (1997-2007 change); morbidity cost of all risk factors (2007-2017 change).

Indirect costs are affected by changes in YLDs/deaths, employment to population ratio and GDP per worker. In the first decade (1997-2007), both employment to population ratio and GDP per worker increased and, as a result, the PVLE increased, too. Thus, for all risks factors, morbidity and mortality costs rose even though, for some age groups, deaths decreased. On the contrary, in the second decade (2007-2017), morbidity and mortality costs fell. Specifically, despite that total YLDs increased for both genders aged 15-69 (except for YLDs related to smoking for males and to SHS exposure for females), morbidity cost of each risk factor, but dietary risks for females, fell. In this case, the reduction in GDP per worker and employment to population ratio for males and younger females outweigh the increase in YLDs. On the other hand, total deaths decreased for both genders aged 15-69 (except for deaths related to smoking and dietary risks for females), resulting to a lower mortality cost for all risk factors.

Mortality cost is also affected by labor productivity and discount rate. In this study, we assumed a 1% growth rate of labor productivity, a standard practice followed by many other studies. If labor productivity is higher than 1%, mortality cost will be higher. As regards discount rate, we assumed non-discounting (r=0%) following the view that human life should not be discounted. However, we also performed a sensitivity analysis assuming a discount rate of 3% which used to be common practice. The higher the discount rate, the lower the mortality cost is. In the case of a 3% discount rate, mortality cost decreased by 16.44% (smoking) to 19.14% (high BMI).

To the best of our knowledge, there is no previous research on the economic cost of dietary risks or SHS exposure. Only Jarvis et al. (2012, 2009) estimated the public healthcare spending attributable to SHS exposure, which is just a part of the direct cost of SHS. As regards the economic cost of tobacco smoking or high BMI, our results are not comparable with previous studies as there are differences in methodology, data and the number of diseases covered. Also, none of the previous studies focuses exclusively on Greece or presents costs analytically by gender, age and disease. From the two existing studies on economic cost of smoking (Goodchild et al., 2018; Jarvis et al., 2012, 2009), our approach is closer to that of Goodchild et al. (2018) but we use different data sources with more recent data and different discount rate for the estimation of mortality cost. However, our major difference is that we have included more tobacco-related diseases. Both studies cover only a certain number of diseases, such as cancers, cardiovascular and respiratory diseases, with Goodchild et al. (2018) also including tuberculosis and lower respiratory infections. One disease category added in our study is musculoskeletal disorder, which was found to be the main cause of smoking-related morbidity cost. As regards the economic cost of high BMI, there are two previous studies (Fry and Finley, 2005;

OECD, 2019). The first one (Fry and Finley, 2005) estimates it pro rata to UK data and does not present the direct and indirect costs separately. The most recent study (OECD, 2019) projects the economic cost of high BMI in 2020-2050. Its main analysis includes the estimation of healthcare cost and labour market cost (through absenteeism, presenteeism, unemployment and early retirement) but not the estimation of premature mortality cost. The mortality cost is estimated separately, using the willingness to pay method, but it is not compared/combined with the other costs because, as the authors explained, it does not reflect actual cost.

As each study, this one has also some limitations. First, data on healthcare expenditure were not available by disease, gender and age, and hence we could not conduct a more detailed analysis of the direct cost. Second, SAFs were IHME estimations based on mortality data, and this might have led to an underestimation of the direct cost. Generally, lack of good data is an issue in studies estimating the economic cost of a risk factor. For example, Goodchild et al. (2018) used data from forty-four countries to estimate a relationship between smoking-attributable fraction of health expenditure and smoking-attributable death rate. Then, they used this estimate to get an approximate calculation of the direct cost of active smoking in 108 countries, for which data on smoking-attributable fraction of health expenditure did not exist. Third, due to lack of data, a further underestimation of the cost may have resulted from not including non-healthcare costs such as transportation to healthcare providers, informal care, business expenses to hire and train replacements for sick employees; or not including indirect costs, such as the value of lost household production. Forth, studies have shown that exposure to passive smoking increases the risk of asthma (Janson, 2004) and excess weight increases the risk of injuries (Finkelstein et al., 2007). However, these data are not provided by GBD study and, thereby, the cost of SHS and high BMI might have been underestimated. Finally, the results of the different risk factors are comparable, but they could not be summed because a possible correlation among them should be taken into account. For example, the total economic cost of smoking and SHS exposure is 3.89%, higher than the economic cost of tobacco use.

From the above, it is concluded that tobacco use and poor diet impose a heavy economic burden in Greece, underlining the need for efficient interventions, including better implementation of existing policies. Starting with tobacco smoking, Greece is one of the countries with the highest tax on tobacco products, accounting for 81.2% of retail price of most common brand[35] (excise tax is 61.9% and VAT is 19.4%) (WHO, 2019). In 2017, the revenues from excise taxes and VAT on tobacco products were

[35] The most common brand is Marlboro. The proportion is even higher for mid-priced and economy brands.

€2.1 billion and €0.6 billion, respectively (Greek Ministry of Finance Financial Data: Balance Sheet and Other Financial Statements.," n.d.). Government could use (part of) these revenues to implement other tobacco policies such as offering help to quit smoking. At the same time, campaigns should inform current smokers about the benefits of the cessation of tobacco use and tobacco-free lifestyles and about the existing and forthcoming cessation programmes. Government should also ban duty-free products and tackle illicit trade as the high cigarette prices in combination with the economic crisis increased the demand for these products. Regarding poor diet and obesity, there is still a lot of work to be done. In recent years, people are better informed about healthy diet. However, the knowledge alone is not enough to change eating habits as healthier products are more expensive than the less healthy in the same food category (e.g., regular chocolate and chocolate with stevia). A solution to this problem might be the implementation of excise ("sin") tax on unhealthy goods, such as sugar-sweetened beverages. As with tobacco taxes, sin taxes raise revenues which could be used to fund other policies, starting with subsidising healthy goods and organizing healthy eating campaigns. In each case, the combination of different policies might have better results in reduction and prevention of smoking and obesity.

Part C: Fiscal Policies for Public Health: Theory and Evidence

In the last Part of this thesis, we study the implementation of fiscal policies for improving public health. Part C consists of two chapters. In Chapter 7, under a theoretical model, we examine the optimal tax on unhealthy good when individuals misperceive the health effects of consuming unhealthy and healthy goods. Next, in Chapter 8, we estimate own- and cross-price elasticities for thirteen food categories, using Greek data. These elasticities are then used to examine different fiscal policies which include taxes on unhealthy goods and/or subsidies on healthy goods.

Chapter 7: Optimal Sin Taxes with Internalities, Earmarking, and Distributional Concern

7.1 Introduction

Sin goods, such as tobacco, alcohol, sugar-sweetened beverages and junk food, are characterized by the instant gratification and later health-related costs. Additionally, they generate negative externalities through harms inflicted on others and healthcare expenditures that are financed through risk pooling. Under-consumption of goods that have positive effects on health leads to similar issues.

Taxes and subsidies aim at changing the consumption of targeted healthy and unhealthy goods via changes in their relative prices. Studies of the optimal sin tax on an unhealthy good differ in how the government is assumed to use the revenue raised by the tax. Some studies assume that tax revenue is used to finance the healthcare system (Aronsson and Thunström, 2008; Cheng and Chu, 2018; Cremer et al., 2012). Others assume that revenue is used to subsidise a healthy good (Yaniv et al., 2009). Some studies allow a combination of these two policies (Cremer et al., 2016). Others assume revenue is returned to society as a lump-sum transfer (Griffith et al., 2018; Haavio and Kotakorpi, 2011; O'Donoghue and Rabin, 2006), while there are also studies in which the tax is used simply for revenue purposes (Bossi et al., 2014; Haavio and Kotakorpi, 2007). Moreover, because sin taxes are often claimed to be regressive, some studies explore not only the corrective but also the distributional implications of such policies (Allcott et al., 2019; Griffith et al., 2018; Haavio and Kotakorpi, 2011; Lockwood and Taubinsky, 2017).

Another issue is that people with unhealthy habits might have self-control or myopia problems. Consumers with self-control problems struggle to reduce the consumption of unhealthy, mostly addictive, goods. Myopic consumers underestimate future benefits and costs from healthy and unhealthy good consumption, respectively. In the literature, studies model these problems in different ways (Cheng and Chu, 2018). Following Cremer et al. (2016), we assume that individuals have misperceptions about the harm caused by health problems related to unhealthy good consumption and the benefits from healthy good consumption. The degree of misperception depends negatively on income; the higher the income, the lower the misperception (Cremer et al., 2016).

The purpose of this Chapter is to examine the optimal fiscal policy when individuals misperceive the negative health effects of unhealthy eating and/or the benefits of healthy eating. We examine two cases regarding the use of tax revenue. In the first case, tax revenue is returned as a lump-sum transfer. In the second case, tax revenue finances a subsidy on a healthy good. For each of the two cases, the selected policy is examined both when government has only efficiency concerns and when distributional concerns exist.

The first-best solution would be an individual-specific tax, based on the level of misperception and consumer preferences. Such a tax, however, is impossible to implement. Thus, the focus is on the second-best option; a uniform tax that maximizes social welfare.

The benchmark model is similar to the one in Cremer et al. (2016). In their model, individuals, who differ in income and level of misperception, have a utility function which depends on the consumption of a healthy good, an unhealthy good and a numeraire good. Government taxes the unhealthy good and revenue is used to subsidise the healthy good and finance healthcare expenditure. The optimal sin tax is that which maximizes utilitarian social welfare under the earmarking constraint. Our model differs from Cremer et al. (2016) in two points. The first one is the way tax revenue is earmarked. The second one is that Cremer et al. (2016) do not account for distributional concerns through the utility function. They do, however, examine the optimal tax in the extreme case of a Rawlsian welfare function that is concerned with the wellbeing of the worst off individual.

The way we introduce distributional concerns is similar to Griffith et al. (2018). The utility function is not linear in numeraire good but increases to a decreasing rate. A key difference with their study is that utility is derived not only from a (taxed) unhealthy good and a numeraire good but also from a (subsidised) healthy good. Moreover, in their study, the internality caused by the consumption of the unhealthy good is placed in a more general context[36]. Finally, when the optimal tax is expressed as an expectation, results are comparable with those of Haavio and Kotakorpi (2011). However, as in Griffith et al. (2018), Haavio and Kotakorpi (2011) do not include the healthy good and assume individuals have self-control problems. Both Haavio and Kotakorpi (2011) and Cremer et al. (2016) investigate the political support of the sin tax, which is not a concern for our study.

Our model combines features of Cremer et al. (2016) and Griffith et al. (2018). The analysis confirms some already known results (Cremer et al., 2016; Griffith et al., 2018; Haavio and Kotakorpi, 2011).

[36] They assume that the unhealthy good consumption generates some internality, I, which is positive.

However, in this study, we extend the interpretation of these results in a wider setting and make a comparative analysis of the different interventions.

The remainder of the Chapter is organized as follows. Section 7.2 describes the benchmark model. Section 7.3 determines the optimal tax on the unhealthy good when raised revenue is returned to individuals as a lump sum. Two cases are examined: (i) when government has only efficiency concerns and (ii) when both efficiency and distributional concerns are present. In Section 7.4, tax revenue is used to finance a subsidy on the healthy good, with and without distributional concerns. Finally, Section 7.5 concludes.

7.2 The Benchmark Model

As in Cremer et al. (2016), there are N individuals *i* with demands for an unhealthy good φ_i (such as sugar-sweetened beverages), a healthy good x_i (such as fruits), and a numeraire good c_i. The healthy-good consumption provides utility $b(x_i)$, which is increasing in x_i at a decreasing rate ($b'(x_i) > 0$ and $b''(x_i) < 0$). Consumption of the unhealthy good generates enjoyment, which is captured by $v(\varphi_i)$, with $v'(\varphi_i) > 0$ and $v''(\varphi_i) < 0$, but has negative health consequences. These negative effects are captured by the harm function $h(\varphi_i)$, which is increasing in φ_i at an increasing rate ($h'(\varphi_i) > 0$ and $h''(\varphi_i) > 0$); that is, we assume that consuming an additional unit of φ_i is more harmful at higher levels of consumption. For individual i, the *true (experienced)* utility is given by

$$U_i = c_i + b(x_i) + v(\varphi_i) - h(\varphi_i) \tag{1}$$

Individuals may misperceive the positive and negative effects of the healthy and the unhealthy good, respectively. The perceived functions of the healthy and the unhealthy good are given by $\delta_i b(x_i)$ and $\beta_i h(\varphi_i)$, respectively, where $\beta_i, \delta_i \in [0,1]$. When there is no misperception, $\delta_i = \beta_i = 1$. Misperception is determined by income (y_i), $\beta_i \equiv \beta(y_i)$ and $\delta_i \equiv \delta(y_i)$. We assume the higher the income, the lower the misperception; $\beta'(y_i) > 0$ and $\delta'(y_i) > 0$. Hence, the *perceived (decision)* utility for individual *i* is given by

$$\widehat{U}_i = c_i + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i) \tag{2}$$

Utility is linear in the numeraire good c_i and demand for healthy and unhealthy good depends only on price. Income affects utility from these goods only indirectly, via misperception ($\beta(y_i)$ and $\delta(y_i)$). Individuals differ in income y, with a distribution function F(y), and hence their misperceptions.

Individuals choose consumption of healthy and unhealthy goods by maximizing their utility function subject to the budget constraint. Assuming that all income is spent on consumption and producer prices are normalized to one, individual i's budget constraint is given by

$$y_i = c_i + x_i + \varphi_i \tag{3}$$

For the optimal level of consumption, individuals should maximize their true utility function (eq. (1)). Due to misperceptions, however, what they maximize is the perceived utility function (2). Thus, individual *i*

$$\max_{c_i, x_i, \varphi_i} \hat{U}_i = c_i + \delta_i b(x_i) + \upsilon(\varphi_i) - \beta_i h(\varphi_i)$$

subject to (3). Substituting (3) in the perceived utility function, the problem becomes

$$\max_{x_i, \varphi_i} \hat{U}_i = y_i - x_i - \varphi_i + \delta_i b(x_i) + \upsilon(\varphi_i) - \beta_i h(\varphi_i) \tag{4}$$

The first order conditions (FOCs), then, are

$$\frac{\partial \hat{U}_i}{\partial x_i} = -1 + \delta_i b'(x_i) = 0 \tag{5}$$

$$\frac{\partial \hat{U}_i}{\partial \varphi_i} = -1 + \upsilon'(\varphi_\iota) - \beta_i h'(\varphi_i) = 0. \tag{6}$$

Individual *i* allocates their income so that perceived marginal benefit of healthy consumption and perceived net marginal utility of unhealthy consumption are equalized.

The second order conditions (SOCs) for a maximum are satisfied, since

$$\frac{\partial^2 \hat{U}_i}{\partial {x_i}^2} = \delta_i b''(\chi_i) < 0$$

$$\frac{\partial^2 \hat{U}_i}{\partial {\varphi_i}^2} = \upsilon''(\varphi_\iota) - \beta_i h''(\varphi_i) < 0$$

and

$$\frac{\partial^2 \hat{U}_i}{\partial {x_i}^2} \frac{\partial^2 \hat{U}_i}{\partial {\varphi_i}^2} - \frac{\partial^2 \hat{U}_i}{\partial x_i \partial \varphi_i} \frac{\partial^2 \hat{U}_i}{\partial \varphi_i \partial x_i} > 0$$

Equations (5) and (6) determine the demand functions for healthy and unhealthy good, $x^* \equiv x(\delta_i)$ and $\varphi^* \equiv \varphi(\beta_i)$, respectively. When there is no misperception ($\delta_i = \beta_i = 1$), perceived utility is identical to true utility function and the maximization problem gives the optimal levels of healthy and unhealthy goods (x^o and φ^o).

In presence of misperception ($\delta_i < 1, \beta_i < 1$), however, individuals deviate from optimal consumption, under-consuming the healthy good ($x^* < x^o$) and over-consuming the unhealthy good ($\varphi^* > \varphi^o$).

Equation (5) states that the perceived marginal utility of healthy good $\left(\delta_i b'(x_i)\right)$ is equal to one. Since $b'(x_i) = \frac{1}{\delta_i} \geq 1$, an extra unit of healthy good increases actual utility by more than one. Marginal utility of healthy good is higher than its marginal cost, and hence the good is under-consumed at equilibrium. According to (6), the perceived *net* marginal utility of the unhealthy good $\left(\upsilon'(\varphi_i) - \beta_i h'(\varphi_i)\right)$ is equal to one. Since $\beta_i < 1$, the actual net marginal utility of unhealthy good is lower than its perceived net marginal utility ($\upsilon'(\varphi_i) - h'(\varphi_i) < \upsilon'(\varphi_i) - \beta_i h'(\varphi_i)$) and the unhealthy good is over-consumed.

For better understanding of why misperception matters, let us consider the following comparative statics with respect to the misperception terms.

$$\frac{\partial x_i^*}{\partial \delta_i} = -\frac{b'(x_i)}{\delta_i b''(x_i)} > 0 \tag{7}$$

$$\frac{\partial \varphi_i^*}{\partial \beta_i} = \frac{h'(\varphi_i)}{\upsilon''(\varphi_\iota) - \beta_i h''(\varphi_i)} < 0 \tag{8}$$

As misperception decreases (δ_i and β_i increase), consumption of healthy good increases while the opposite occurs with the consumption of unhealthy good. Thus, as misperception decreases and misperception coefficients tend to their ideal level ($\delta_i = \beta_i = 1$), consumption of healthy (unhealthy) good increases (decreases) approaching optimal levels (x^o and φ^o).

Because the level of misperception is negatively correlated with income, low-income individuals tend to consume more of the unhealthy good and less of the healthy good than high-income individuals. To see it, let us consider the individuals with the lowest (y_l) and the highest income levels (y_h). Then, equation (6) becomes

$$\upsilon'(\varphi_l) - \beta_l h'(\varphi_l) = 1$$

$$\upsilon'(\varphi_h) - \beta_h h'(\varphi_h) = 1$$

for the lowest- and highest-income groups, respectively. This implies that

$$\upsilon'(\varphi_h) - \upsilon'(\varphi_l) = \beta_h h'(\varphi_h) - \beta_l h'(\varphi_l)$$

If $\upsilon'(\varphi_l) > \upsilon'(\varphi_h)$: then, (i) $\varphi_l < \varphi_h$, since $\upsilon''(\varphi) < 0$, and (ii) $\beta_l h'(\varphi_l) > \beta_h h'(\varphi_h)$, which in turn implies $h'(\varphi_l) > h'(\varphi_h)$ given $\beta_l < \beta_h$. But if $h'(\varphi_l) > h'(\varphi_h)$, then $\varphi_l > \varphi_h$, since $h''(\varphi) > 0$, which is a contradiction.

If $\upsilon'(\varphi_h) > \upsilon'(\varphi_l)$: then, (i) $\varphi_h < \varphi_l$, since $\upsilon''(\varphi) < 0$, and (ii) $\beta_h h'(\varphi_h) > \beta_l h'(\varphi_l)$. Assuming $\beta_h h'(\varphi_h) > \beta_l h'(\varphi_l)$ is consistent with $h'(\varphi_h) < h'(\varphi_l)$ (that is, $\frac{\beta_l}{\beta_h} h'(\varphi_l) < h'(\varphi_h) < h'(\varphi_l)$), and hence $\varphi_h < \varphi_l$**.** Thus, the lowest-income individuals consume more of the unhealthy good relatively to the highest-income individuals.

Equation (5) can be written as

$$\delta_l b'(x_l) = 1 \Rightarrow b'(x_l) = \frac{1}{\delta_l} \quad \text{for the lowest-income individuals}$$

$$\delta_h b'(x_h) = 1 \Rightarrow b'(x_h) = \frac{1}{\delta_h} \quad \text{for the highest-income individuals}$$

which implies that $b'(x_l) > b'(x_h)$ as $\delta_l < \delta_h$ and $x_l < x_h$ due to $b''(x) < 0$. Thus, the lowest-income individuals consume less healthy good than the highest-income individuals.

The presence of misperception leads to sub-optimal choices regarding healthy and unhealthy consumption, as well as regressivity concerns. In what follows, we examine possible government interventions to correct this failure.

7.3 Corrective Health Taxes

We start by examining the effect of misperception regarding the unhealthy good (say, fat) on individual consumption, implementing a health (fat) tax. The first-best option would be an individual-specific tax, based on consumer preferences and the level of misperception. Such a tax, however, is too complex to be implemented. We focus on the second-best solution, that is, finding a uniform specific tax which maximizes social welfare. Since prices are normalized to one, whether the tax is ad valorem or specific is of no relevance. In this Section, the revenue raised is returned to consumers as a lump-sum. We distinguish two cases, one where government has only efficiency concerns and one where both efficiency and distributional concerns are present.

7.3.1 Purely Corrective Taxation with Lump-sum Transfers

Let the uniform tax on the unhealthy good (fat tax) be set at a rate t per unit. The tax revenue (R) collected is

$$R = t\int_{y_l}^{y_h} \varphi_i(y)\mathrm{dF(y)} = t\Phi = t\bar{\varphi}N \tag{9}$$

where Φ is total consumption and $\bar{\varphi}$ the average consumption of the unhealthy good. The effect of a tax change on R is given by

$$\frac{\partial \mathrm{R}}{\partial \mathrm{t}} = \int_{\mathrm{y_l}}^{\mathrm{y_h}} \varphi_i^{*}\mathrm{dF(y)} \quad + \mathrm{t}\int_{\mathrm{y_l}}^{\mathrm{y_h}} \frac{\partial \varphi_i^{*}}{\partial \mathrm{t}}\mathrm{dF(y)} = \Phi + \mathrm{t}\frac{\partial \Phi}{\partial \mathrm{t}} = \left(\bar{\varphi} + t\frac{\partial \bar{\varphi}}{\partial t}\right)N \tag{10}$$

Tax revenue is returned to consumers as a lump sum transfer, $r_i = {}^{R}\!/_{N} = t\bar{\varphi}$. Taking now into account the fat tax and the lump-sum transfer, individual i’s budget constraint is given by

$$y_i + r_i = c_i + x_i + (1+t)\varphi_i \tag{11}$$

Thus, the individual’s maximization problem is now

$$\max_{c_i, x_i, \varphi_i} \hat{\mathrm{U}}_i = c_i + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i)$$

$$\text{s.t } y_i + r_i = c_i + x_i + (1+t)\varphi_i$$

In absence of redistributive motives, we assume utility is linear in the numeraire good and $MU_y = 1$ for all individuals. The government places the same value on an additional unit of money given to all individuals regardless of their position in the income distribution.

Solving the budget constraint for c_i and substituting it in the perceived utility function, the problem reduces to

$$\max_{x_i,\varphi_i} \hat{U}_i = y_i + r_i - x_i - (1+t)\varphi_i + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i) \tag{12}$$

The FOCs now are

$$\frac{\partial \hat{U}_i}{\partial x_i} = -1 + \delta_i b'(x_i) = 0 \tag{13≡5}$$

$$\frac{\partial \hat{U}_i}{\partial \varphi_i} = -(1+t) + v'(\varphi_i) - \beta_i h'(\varphi_i) = 0 \tag{14}$$

The comparative statics with respect to misperception and tax are given by

$$\frac{\partial x_i^*}{\partial \delta_i} = -\frac{b'(x_i)}{\delta_i b''(x_i)} > 0 \tag{15≡7}$$

$$\frac{\partial \varphi_i^*}{\partial t} = \frac{1}{v''(\varphi_i) - \beta_i h''(\varphi_i)} < 0 \tag{16}$$

$$\frac{\partial \varphi_i^*}{\partial \beta_i} = \frac{h'(\varphi_i)}{v''(\varphi_i) - \beta_i h''(\varphi_i)} = h'(\varphi_i)\frac{\partial \varphi_i^*}{\partial t} < 0 \tag{17}$$

$$\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} = \frac{-[v'''(\varphi_i) - \beta_i h'''(\varphi_i)]\frac{\partial \varphi_i}{\partial \beta_i} + h''(\varphi_i)}{[v''(\varphi_i) - \beta_i h''(\varphi_i)]^2} \tag{18}$$

As there is no intervention concerning the healthy good, equations (13) and (15) will be the same as equations (5) and (7), respectively. Demand for the healthy good is as before $x^* \equiv x(\delta_i)$ and the individuals continue to under-consume it. As given by equation (14), the demand for the unhealthy good is now $\varphi^* \equiv \varphi(\beta_i, t)$; consumption of fat good depends on the level of misperception and the fat tax. As shown in (16), when the tax increases, consumption of the unhealthy good falls. Thus, the optimal consumption under taxation is lower than that in the no-tax situation ($\varphi_i^*(t > 0) < \varphi_i^*(t = 0)$). Consumers, however, do not reach the first-best (φ^o); the uniform fat tax is a second-best option and only corrects the average misperception, as we will show below.

As regards the size of the tax effect on unhealthy good demand, equation (16) shows that, in absolute values, the higher the slope (the rate of change) of the marginal utility and/or the marginal harm of the unhealthy good, the smaller the tax effect on unhealthy good consumption. That is, if $v''(\varphi_i) - \beta_i h''(\varphi_i) > -1$, then $\left|\frac{\partial \varphi_i^*}{\partial t}\right| > 1$ and an extra unit of fat tax decreases unhealthy good consumption by more than one.

Regarding equation (18),

$$\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} > 0 \; if \;\; v'''(\varphi_i) - \beta_i h'''(\varphi_i) \geq 0$$

for which $v'''(\varphi_i) > 0$ and $h'''(\varphi_i) < 0$ are sufficient. Actually for $\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i}$ to be positive, the numerator must be positive too, which requires

$$h'''(\varphi_i) < \frac{v'''(\varphi_i)}{\beta_i} - \frac{h''(\varphi_i)}{\beta_i \, {}^{\partial \varphi_i}/_{\partial \beta_i}}.$$

Using (17), this can be written as

$$h'''(\varphi_i) < \frac{1}{\beta_i}\left[v'''(\varphi_i) - \frac{h''(\varphi_i)\big(v''(\varphi_i) - \beta_i h''(\varphi_i)\big)}{h'(\varphi_i)}\right] \tag{19}$$

Assuming prudence, $v'''(\varphi_i) > 0$. Thus, the right-hand side of (19) is positive, too. Inequality (19) is a sufficient condition for $\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} > 0,$ and it is clearly less demanding than $h'''(\varphi_i) < 0$.

For the rest of the chapter, we assume $\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} > 0,$ which holds for most functional forms and is supported by empirical evidence (see, e.g., Haavio and Kotakorpi (2011, p.79) regarding the effect of an increase in the level of self-control problems on the tax effect on consumption). This implies that as misperception decreases (β_i increases), the tax effect on unhealthy good demand (in absolute value) decreases too.

Government chooses the tax rate *t* to maximize social welfare, that is, the sum of individuals' *true* indirect utility function:

$$\max_{\mathrm{t}} \; \mathrm{W} = \int_{\mathrm{y_l}}^{\mathrm{y_h}} V_i(t) \, \mathrm{dF(y)}, \tag{20}$$

where $V_i(t)$ is the *true* indirect utility function defined as

$$V_i(t) = y_i + r_i - x_i - (1+t)\varphi_i(t) + \; b(x_i) + v\big(\varphi_i(t)\big) - h\big(\varphi_i(t)\big)$$

Then, the FOC of (20) with respect to t is

$$\frac{\partial W}{\partial t} = \int_{y_l}^{y_h} [-(1+t) + \upsilon'(\varphi_i^*) - h'(\varphi_i^*)] \frac{\partial \varphi_i^*}{\partial t} dF(y) + t\frac{\partial \overline{\varphi}}{\partial t} = 0 \qquad (21)$$

where use has been made of (10) to derive

$$\frac{\partial \int_{y_l}^{y_h} r_i dF(y)}{\partial t} = \overline{\varphi} + t\frac{\partial \overline{\varphi}}{\partial t} \qquad (22)$$

Finally, using (14),

$$\frac{\partial W}{\partial t} = \int_{y_l}^{y_h} [-(1-\beta_i)h'(\varphi_i^*)] \frac{\partial \varphi_i^*}{\partial t} dF(y) + t\frac{\partial \overline{\varphi}}{\partial t} = 0$$

Solving for t, the second-best optimal tax is

$$t^* = \frac{\int_{y_l}^{y_h}(1-\beta_i)h'(\varphi_i^*)\frac{\partial \varphi_i^*}{\partial t} dF(y)}{\frac{\partial \overline{\varphi}}{\partial t}} \qquad (23)$$

where $(1-\beta_i)h'(\varphi_i^*)$ is individual i's overlooked marginal internal harm caused by consumption of the unhealthy good; $\frac{\partial \varphi_i^*}{\partial t}$ is the individual fat consumption response to tax. Thus, the numerator in (23) is the average marginal bias weighted by the individual demand response to fat tax. The optimal tax corrects for the average misperceived health effects of the fat good, weighted by the average demand response to tax, $\frac{\partial \overline{\varphi}}{\partial t}$. When individuals misperceive the harm ($\beta_i < 1$), the fat tax is positive. When there is no such misperception ($\beta_i = 1$), the fat tax is zero. Note that our equation (23) relates to equation (A.4) in Cremer et al. (2016), when individuals do not impose externalities on the healthcare system (as assumed in our model).

Result 1: *When the tax is purely corrective, with the proceeds returned to consumers as a lump-sum, the second best Pigouvian tax is the weighted average of individual misperceptions regarding marginal harm.*

The optimal tax is expressed as a weighted (by the tax effect on demand for the unhealthy good) average of marginal internalities. In absolute terms, the tax effect on overlooked internal harm is lower for high-income individuals as they face lower misperception and their consumption of unhealthy good is closer to the first-best optimum. The opposite holds for low-income individuals. That is,

$$\left|(1-\beta_h)h'({\varphi_h}^*)\frac{\partial {\varphi_h}^*}{\partial t}\right| < \left|(1-\beta_l)h'({\varphi_l}^*)\frac{\partial {\varphi_l}^*}{\partial t}\right| \quad (24)$$

Proof of (24): Since $\beta_h > \beta_l$, then $1-\beta_h < 1-\beta_l$. Moreover, since $\varphi_l > \varphi_h$ and $h''(\varphi_i) > 0$, it implies $h'(\varphi_h) < h'(\varphi_l)$. Thus, to compare $(1-\beta_h)h'({\varphi_h}^*)\frac{\partial {\varphi_h}^*}{\partial t}$ with $(1-\beta_l)h'({\varphi_l}^*)\frac{\partial {\varphi_l}^*}{\partial t}$, we need to know the relationship between $\frac{\partial {\varphi_h}^*}{\partial t}$ and $\frac{\partial {\varphi_l}^*}{\partial t}$. Using equation (16),

$$\frac{\partial \varphi_h}{\partial t} = \frac{1}{\upsilon''(\varphi_h) - \beta_h h''(\varphi_h)} \qquad \text{for highest-income individuals}$$

$$\frac{\partial \varphi_l}{\partial t} = \frac{1}{\upsilon''(\varphi_l) - \beta_l h''(\varphi_l)} \qquad \text{for lowest-income individuals}$$

Assuming $h'''(\varphi_i) < 0$,

$$h''(\varphi_h) > h''(\varphi_l) \;\Rightarrow$$

$$\beta_h h''(\varphi_h) > \beta_l h''(\varphi_l) \;\Rightarrow$$

$$-\beta_h h''(\varphi_h) < -\beta_l h''(\varphi_l) \;\Rightarrow$$

$$(\upsilon''(\varphi_h) < \upsilon''(\varphi_l) \text{ since assumed } \upsilon'''(\varphi_i) > 0)$$

$$\upsilon''(\varphi_h) - \beta_h h''(\varphi_h) < \upsilon''(\varphi_l) - \beta_l h''(\varphi_l) \;\Rightarrow$$

$$\frac{1}{\upsilon''(\varphi_h) - \beta_h h''(\varphi_h)} > \frac{1}{\upsilon''(\varphi_l) - \beta_l h''(\varphi_l)} \;\Rightarrow$$

$$\frac{\partial \varphi_h}{\partial t} > \frac{\partial \varphi_l}{\partial t}$$

Finally, given $\frac{\partial \varphi_i}{\partial t} < 0$, we get

$$\left|\frac{\partial \varphi_h}{\partial t}\right| < \left|\frac{\partial \varphi_l}{\partial t}\right|$$

which is based on the assumption $\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} > 0$ and implies (24) holds. *QED.*

Equation (24) implies that the second-best optimal tax can be too large for those with higher income (lower consumption of unhealthy good) and too small for those with lower income (higher consumption of unhealthy good). The tax is expected to be a compromise since we cannot use first-best taxes.

Result 2: *The second best Pigouvian tax is higher (ceteris paribus),*

- *the lower the tax effect on average demand for unhealthy good*
- *the higher the degree of misperception (overlooked harm)*
- *the higher the marginal internal harm.*

Note that equation (23) can be rewritten as

$$t^* = \frac{E\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i})\frac{\partial \varphi_\mathrm{i}}{\partial \mathrm{t}}\right]}{\frac{\partial \overline{\varphi}}{\partial \mathrm{t}}} \tag{25}$$

Using the formula of covariance,[37] equation (25) becomes

$$t^* = \frac{E[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i})]E\left(\frac{\partial \varphi_\mathrm{i}}{\partial \mathrm{t}}\right)}{\frac{\partial \overline{\varphi}}{\partial \mathrm{t}}} + \frac{Cov\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i}), \left|\frac{\partial \varphi_\mathrm{i}}{\partial \mathrm{t}}\right|\right]}{\left|\frac{\partial \overline{\varphi}}{\partial \mathrm{t}}\right|}$$

which leads to

[37] $\mathrm{Cov}(X,Y) = E[XY] - E[X]E[Y]$, i.e., covariance is "expectation of product minus product of expectations". Thus, $E[XY] = E[X]E[Y] + \mathrm{Cov}(X,Y)$ (see, e.g., Kyle Siegrist (2020))

$$t^{*} = E[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i})] + \frac{Cov\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i}), \left|\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}}\right|\right]}{\left|\frac{\partial\overline{\varphi}}{\partial \mathrm{t}}\right|} \tag{26}$$

The first term of equation (26) is the average overlooked marginal internal harm caused by the consumption of the unhealthy good and is positive. The second term is an adjustment term based on the covariance of overlooked internal harm and the responsiveness of the unhealthy good consumption to the tax (in absolute value). The sign of the second term is ambiguous and depends on $Cov\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i}), \left|\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}}\right|\right]$.

Note the term $Cov\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i}), \left|\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}}\right|\right]$ is the covariance between consumers' heterogeneity in internalities (the extent of their misperception) and the tax-responsiveness of their unhealthy consumption. It captures the extent to which misperception correction is concentrated on those that consume more of the unhealthy good. Therefore, it reflects the possibility to discourage unhealthy consumption specifically from those with the highest internality.

If $Cov\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i}), \left|\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}}\right|\right] > 0$, consumption of the unhealthy good from those with greatest internalities (lower β_i) is more sensitive to the tax increase. Hence, the second term in (26) would be positive and the optimal tax would increase, since it would increase welfare of those mostly affected. If $Cov\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i}), \left|\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}}\right|\right] < 0$, consumption of the unhealthy good from those with greatest internalities (lower β_i) is less sensitive to the tax increase. Hence, the second term in (26) would be negative and the optimal tax would decrease since it would be less effective.

Note that an increase in β_i leads to a decrease in φ_i, and hence a decrease in $\mathrm{h}'(\varphi_\mathrm{i})$ since $\mathrm{h}''(\varphi_\mathrm{i}) > 0$; that is, term $(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i})$ decreases. For $Cov\left[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i}), \left|\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}}\right|\right] > 0$, we need $\left|\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}}\right|$ to also decrease as $\beta_i$increases; that is $\frac{\partial^2\varphi_i}{\partial t\partial\beta_i} > 0$, as assumed above. The tax effect on unhealthy consumption is increasing (note $\frac{\partial\varphi_\mathrm{i}}{\partial \mathrm{t}} < 0$) as misperception increases. The demand of more biased consumers with high level of consumption is more responsive in absolute terms to the tax relatively to the less biased ones. Note demand can still be less price elastic for the consumers with the highest misperception.

Result 3: *Assuming prudence and no distributional concerns, the second best Pigouvian tax is higher (ceteris paribus) than the average misperception internality:*

$$t^* > E[(1-\beta_i)\mathrm{h}'(\varphi_\mathrm{i})].$$

Taxation has a larger impact on consumers with the higher misperception and, hence, the benefit from their behavioural adjustment outweighs the cost to the consumers with lower than average degree of misperception.

Result 3 relates to Haavio and Kotakorpi (2011), proposition 3, stating that the optimal tax is higher than the average distortion from self-control problems.

Note that, since low-income individuals consume more of the unhealthy good relatively to high-income individuals, the tax - rebate scheme is regressive. However, assuming $\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} > 0$, the tax effect on unhealthy good consumption is higher (in absolute value) for low-income individuals. As a result, for low-income individuals, the health benefits are expected to be higher, since $h'(\varphi_i) > 0$ and $h''(\varphi_i) > 0$. Thus, the tax is income-regressive but health-progressive.

Next section analyzes the effects of the fat tax with distributional considerations.

7.3.2 Corrective Taxes with Lump-sum Transfers and Distributional Concerns

To deal with distributional concerns, assume now utility from the numeraire good is $v(c_i)$, with $v'(c_i) > 0$ and $v''(c_i) < 0$. Government values an additional unit of money given to low-income individuals more due to diminishing marginal utility of income. Now each individual receives

$$r_i = \gamma_\mathrm{i}\mathrm{t}\int \varphi_\mathrm{i}\mathrm{dF(y)} = \gamma_i t \Phi.$$

and their maximization problem is

$$\max_{c_i, x_i, \varphi_i} \hat{\mathrm{U}}_i = v(c_i) + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i)$$

$$\text{s.t } y_i + r_i = c_i + x_i + (1+t)\varphi_i$$

The Langrangean for this problem is then

$$L_i = v(c_i) + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i) - \lambda_i[c_i + x_i + (1+t)\varphi_i - y_i - r_i] \tag{27}$$

where λ_i is the Langrange multiplier capturing the marginal effect on utility of relaxing the budget constraint by one unit. That is, $\lambda_i = MU_{y_i} = v'(c_i) > 0$.

The FOCs with respect to x_i and φ_i are

$$-\lambda_i + \delta_i b'(x_i) = 0 \tag{28}$$

$$-(1+t)\lambda_i + v'(\varphi_\iota) - \beta_i h'(\varphi_i) = 0 \tag{29}$$

The comparative statics with respect to misperception and tax are given by

$$\frac{\partial x_i^*}{\partial \delta_i} = -\frac{b'(x_i)}{\delta_i b''(x_i)} > 0 \tag{30≡15}$$

$$\frac{\partial \varphi_i^*}{\partial t} = \frac{\lambda_i}{v''(\varphi_\iota) - \beta_i h''(\varphi_i)} < 0 \tag{31}$$

$$\frac{\partial \varphi_i^*}{\partial \beta_i} = \frac{h'(\varphi_i)}{v''(\varphi_\iota) - \beta_i h''(\varphi_i)} = h'(\varphi_i)\frac{1}{\lambda_i}\frac{\partial \varphi_i^*}{\partial t} < 0 \tag{32}$$

$$\frac{\partial^2 \varphi_i^*}{\partial t \partial \beta_i} = \lambda_i \; \frac{-[v'''(\varphi_\iota) - \beta_i h'''(\varphi_i)]\frac{\partial \varphi_i}{\partial \beta_i} + h''(\varphi_i)}{[v''(\varphi_\iota) - \beta_i h''(\varphi_i)]^2} \tag{33}$$

FOC (33) is such as (18) multiplied by λ_i and assumed positive. The explanation of this positivity is the same as the one for equation (33), since $\lambda_i > 0$.

The government solves

$$\max_t W = \int_{y_l}^{y_h} \left[v(c_i) + b(x_i) + v(\varphi_i) - h(\varphi_i) - \lambda_i[c_i + x_i + (1+t)\varphi_i - y_i - r_i]\right] dF(y)$$

Using $\frac{\partial r_i}{\partial t} = \gamma_i \Phi + t\gamma_i \frac{\partial \Phi}{\partial t}$, the FOC is

$$\frac{\partial W}{\partial t} = \int_{y_l}^{y_h} \left\{[-\lambda_i\,(1+t) + v'(\varphi_i) - h'(\varphi_I)\,]\frac{\partial \varphi_i}{\partial t} - \lambda_i \varphi_i + \lambda_i \frac{\partial r_i}{\partial t}\right\} dF(y)$$

$$= \int_{y_l}^{y_h} \left\{[-\,(1-\beta_i)h'(\varphi_i{}^*)\,]\frac{\partial \varphi_i}{\partial t} - \lambda_i \varphi_i + \lambda_i \gamma_i \Phi + t\lambda_i \gamma_i \frac{\partial \Phi}{\partial t}\right\} dF(y) = 0 \tag{34}$$

Then

$$t^* = \frac{\int_{y_l}^{y_h}(1-\beta_i)h'(\varphi_i)\frac{\partial \varphi_i}{\partial t}dF(y)}{\frac{\partial \Phi}{\partial t}\int_{y_l}^{y_h}\lambda_i \gamma_i dF(y)} + \frac{\int_{y_l}^{y_h}\lambda_i \varphi_i dF(y) - \int_{y_l}^{y_h}\lambda_i \gamma_i \sum_i \varphi_i \, dF(y)}{\frac{\partial \Phi}{\partial t}\int_{y_l}^{y_h}\lambda_i \gamma_i dF(y)} \quad (35)$$

Denoting by $\bar{\lambda} = \sum_i \lambda_i \gamma_i$ the average marginal utility of income weighted by the fraction of tax rebate individual receives, the optimal tax is

$$t^* = \frac{1}{\bar{\lambda}}\left\{\frac{\int_{y_l}^{y_h}(1-\beta_i)h'(\varphi_i)\frac{\partial \varphi_i}{\partial t}dF(y)}{\frac{\partial \Phi}{\partial t}} + \frac{\int_{y_l}^{y_h}(\lambda_i - \bar{\lambda})\varphi_i dF(y)}{\frac{\partial \Phi}{\partial t}}\right\} \quad (36)$$

If $\gamma_i = {}^1/_N$ or $\lambda_i = \bar{\lambda}$ the tax is purely corrective and (36) reduces to (23). Equation (36) is similar to equation (3.4) in Griffith et al. (2018), who assume there is an internality but do not model its exact cause.

The first term on the right-hand side in (36) refers to efficiency gains: it captures the degree at which the tax reduces unhealthy consumption from those that face the greater misperception. This bias correction is more valuable when the more tax responsive consumers are also the ones with the greater bias and marginal harm.

The second term on the right-hand side in (36) refers to potential regressivity cost. If individuals with $\lambda_i > \bar{\lambda}$, that is low-income individuals, consume a lot of the taxed good, then incidence falls mostly on them to whom the government wishes to redistribute. The tax - rebate combination is regressive in this case. If individuals with $\lambda_i < \bar{\lambda}$, that is high-income individuals, consume a lot of the taxed good, then the incidence falls mostly on them from whom government wishes to redistribute and the tax-rebate combination is progressive.

In section 7.2, we showed that low-income individuals (here those with $\lambda_i > \bar{\lambda}$) consume more of the unhealthy good (and less of the healthy one) relatively to high-income individuals. Hence

Result 4: *In presence of distributional concerns, the second-best optimal tax is a trade-off between efficiency and equity, and the optimal tax rate is lower relative to the case of no distributional concerns.*

Then, compared to the case with no distributional concerns, the optimal tax is less regressive relative to income but also less progressive relative to health. . With the appropriate redistribution, this scheme might be even income progressive as low-income individuals is likely to receive a lump-sum transfer higher than the amount paid on tax.

7.4 Corrective Health Taxes and Subsidies

Assume now the government taxes the harmful good and subsidises the healthy one with the proceeds of the tax. We expect the effect on the consumption of the two goods to be more pronounced as the use of both fiscal instruments boosts the change in relative prices.

7.4.1 Purely Corrective Taxes and Subsidies

Consumer *i* chooses x_i and φ_i to maximize their perceived utility function subject to the new budget constraint. The individual's maximization problem is now

$$\max_{c_i, x_i, \varphi_i} \hat{U}_i = c_i + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i)$$

$$\text{s.t } y_i = c_i + (1-s)x_i + (1+t)\varphi_i$$

where *s* is the unit subsidy on the healthy consumption.

Solving budget constraint for c_i and substituting it in the perceived utility function, the problem is

$$\max_{x_i, \varphi_i} \hat{U}_i = y_i - (1-s)x_i - (1+t)\varphi_i + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i) \quad (37)$$

Then, the FOCs with respect to x_i and φ_i are

$$\delta_i b'(x_i) - (1-s) = 0 \quad (38)$$

$$v'(\varphi_i) - \beta_i h'(\varphi_i) - (1+t) = 0 \quad (39\equiv14)$$

Differentiating (38) and (39) with respect to tax and subsidy,

$$\frac{\partial x_i}{\partial s} = -\frac{1}{\delta_i b''(x_i)} > 0 \quad (40)$$

$$\frac{\partial \varphi_i}{\partial t} = -\frac{-1}{v''(\varphi_i) - \beta_i h''(\varphi_i)} < 0 \quad (41\equiv16)$$

Equations (39) and (41) are the same as equations (14) and (16), respectively. As explained in Section 7.3.1, the optimal level of consumption of the unhealthy good is relatively lower under taxation: $\varphi_i^*(t > 0) < \varphi_i^*(t = 0)$. On the other hand, based on equation (38), demand for healthy good depends on the level of misperception and the subsidy; the demand for unhealthy good is now $x^* \equiv x(\delta_i, s)$. Equation (40) shows that, when the subsidy increases, consumption of healthy good increases too. Thus, it implies that the optimal level of consumption of the healthy good under subsidisation is relatively higher: $x_i^*(s > 0) > x_i^*(s = 0)$.

As regards the size of the subsidy effect on healthy good demand, equation (40) shows that it depends on the degree of misperception δ_i in relation to the second derivative $b''(x_i)$. If $-\delta_i b''(x_i) > 1$, which implies $\delta_i > \frac{\mathbf{1}}{-b''(\chi_i)}$ and $|b''(\chi_i)| > 1$ ($since\ \delta_i \in [0,1]$), then $0 < \frac{\partial \chi_i}{\partial s} < 1$: that is, an extra unit of subsidy increases healthy good consumption by less than one. Generally, the higher the slope (the rate of change) of the marginal utility of the healthy good, the smaller the subsidy effect on healthy good consumption.

The ratio of subsidy effect to tax effect (in absolute value) is

$$\frac{\frac{\partial x_i}{\partial s}}{\left|\frac{\partial \varphi_i}{\partial t}\right|} = \frac{\frac{-1}{\delta_i b''(x_i)}}{\frac{-1}{v''(\varphi_i) - \beta_i h''(\varphi_i)}} = \frac{v''(\varphi_i) - \beta_i h''(\varphi_i)}{\delta_i b''(x_i)} \tag{42}$$

The subsidy effect is bigger than tax effect, if $v''(\varphi_i) - \beta_i h''(\varphi_i) < \delta_i b''(x_i)$, since both the numerator and denominator are negative, or $|v''(\varphi_i) - \beta_i h''(\varphi_i)| > |\delta_i b''(x_i)|$. Thus, the subsidy effect is relatively bigger if a one unit increase in consumption reduces the perceived *net* marginal utility of the unhealthy good $(v'(\varphi_i) - \beta_i h'(\varphi_i))$ more than the perceived marginal benefit of the healthy good $\left(\delta_i b'(x_i)\right)$.

The FOCs imply that the perceived marginal rate of substitution, $MRS_{\varphi,x}$, is now lower than in the absence of the subsidy, and more of x_i^* is consumed :

$$\frac{perceived\ MU_x}{perceived\ MU_\varphi} = \frac{1-s}{1-t} < \frac{1}{1-t}$$

Note that, using (38) and (40), the comparative statics with respect to δ_i are

$$\frac{\partial x_i}{\partial \delta_i} = -\frac{b'(x_i)}{\delta_i b''(x_i)} = b'(x_i)\frac{\partial x_i}{\partial s} > 0 \tag{43}$$

and

$$\frac{\partial^2 x_i}{\partial s \partial \delta_i} = \frac{b''(x_i) + \delta_i b'''(x_i)\frac{\partial x_i}{\partial \delta_i}}{[\delta_i b''(x_i)]^2} \tag{44}$$

Using (43), (44) becomes

$$\frac{\partial^2 x_i}{\partial s \partial \delta_i} = \frac{-\delta_i b'''(x_i)\frac{b'(x_i)}{\delta_i b''(x_i)} + b''(x_i)}{[\delta_i b''(x_i)]^2} \tag{45}$$

Then,

$$\frac{\partial^2 x_i}{\partial s \partial \delta_i} \gtreqless 0 \quad \text{iff} \quad -b'''(x_i)\frac{b'(x_i)}{b''(x_i)} + b''(x_i) = b'(x_i)\left[-\frac{b'''(x_i)}{b''(x_i)} + \frac{b''(x)}{b'(x_i)}\right] \gtreqless 0$$

The first term in square brackets is the absolute risk prudence coefficient and the second is the absolute risk aversion coefficient. Since prudence is defined by $b'''(\chi_i) > 0$ and assuming decreasing absolute risk aversion (DARA),[38]

$$-\frac{b'''(\chi_i)}{b''(\chi_i)} > -\frac{b''(\chi_i)}{b'(\chi_i)}$$

and

$$\frac{\partial^2 \chi_i}{\partial s \partial \delta_i} > 0$$

Thus, as misperception decreases (δ_i increases), the subsidy effect on healthy good demand increases.

Note that, using (39) and (41) the comparative statics with respect to β_i are

$$\frac{\partial \varphi_i^*}{\partial \beta_i} = \frac{h'(\varphi_i)}{v''(\varphi_i) - \beta_i h''(\varphi_i)} = h'(\varphi_i)\frac{\partial \varphi_i^*}{\partial t} < 0 \tag{46≡(17)}$$

$$\frac{\partial^2 \varphi_i^*}{\partial t \partial \beta_i} = \frac{-[v'''(\varphi_i) - \beta_i h'''(\varphi_i)]\frac{\partial \varphi_i}{\partial \beta_i} + h''(\varphi_i)}{[v''(\varphi_i) - \beta_i h''(\varphi_i)]^2} \tag{47≡(18)}$$

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[38] The ratio of the absolute risk prudence $(-b'''(\chi_i)/b''(\chi_i))$ to the absolute risk aversion $(-b''(\chi_i)/b'(\chi_i))$ should be higher than 1. For more details about DARA, see Bertrand and Prigent (2010), footnote 6.

Equations (46) and (47) are the same as equations (17) and (18), respectively. As already mentioned, based on assumptions and explanation made for (18), we assume that $\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} > 0$.

Government chooses the tax and subsidy rate to maximize social welfare

$$\int_{y_l}^{y_h} \left[y_i - (1-s)x_i - (1+t)\varphi_i + b(x_i) + v(\varphi_i) - h(\varphi_i)\right] \mathrm{dF(y)}$$

$$\mathrm{s.t} \quad t\bar{\varphi} = s\bar{x} \quad \text{or} \quad t\int_{y_l}^{y_h} \varphi_i \, \mathrm{dF(y)} = s\int_{y_l}^{y_h} x_i \, \mathrm{dF(y)}$$

Using the constraint of the balanced budget, government maximizes

$$W = \int_{y_l}^{y_h} [y_i - x_i - \varphi_i + b(x_i) + v(\varphi_i) - h(\varphi_i)] \, d\mathrm{F}(y)$$

Then,

$$\frac{\partial W}{\partial t} = \int_{y_l}^{y_h} [v'(\varphi_i) - h'(\varphi_i) - 1] \frac{\partial \varphi_i}{\partial t} \mathrm{dF(y)} = 0 \tag{48}$$

and using (41)

$$\int_{y_l}^{y_h} [t - (1 - \beta_i)h'(\varphi_i)] \frac{\partial \varphi_i}{\partial t} \mathrm{dF(y)} = 0$$

This gives the optimal tax

$$t^* = \frac{\int_{y_l}^{y_h} (1 - \beta_i)h'(\varphi_i) \frac{\partial \varphi_i}{\partial t} \mathrm{dF(y)}}{\frac{\partial \bar{\varphi}}{\partial t}} \tag{49}$$

which is the same as in (23) and the optimal tax is higher than the average internality. Moreover, since $\frac{\partial t^*}{\partial \beta_i} < 0$, the optimal tax is decreasing in β_i.

Note that (49) can be rewritten as

$$\overline{\varphi}\varepsilon_{\overline{\varphi},t} = \int_{y_l}^{y_h} (1-\beta_i) h'(\varphi_i) \frac{\partial \varphi_i}{\partial t} \mathrm{dF(y)} \tag{50}$$

That is, at the optimum, the average consumption weighted by its tax elasticity is equal to the average marginal internality weighted by the tax effect on demand.

Differentiating the welfare function with respect to s, we have

$$\frac{\partial W}{\partial s} = \int_{y_l}^{y_h} [-1 + b'(\chi_\iota)] \frac{\partial \chi_i}{\partial s} \mathrm{dF(y)} = 0 \tag{51}$$

Using (38)

$$\int_{y_l}^{y_h} [(1-\delta_i) b'(\chi_\iota) - s] \frac{\partial \chi_i}{\partial s} \mathrm{dF(y)} = 0$$

and the optimal subsidy is

$$s^* = \frac{\int_{y_l}^{y_h} (1-\delta_i) b'(x_i) \frac{\partial x_i}{\partial s} \mathrm{dF(y)}}{\frac{\partial \bar{x}}{\partial s}} \tag{52}$$

The optimal subsidy is equal to the weighted average marginal internality, that is, the average bias of consumers who are at the margin at the subsidised price. Moreover, $\frac{\partial s^*}{\partial \delta_i} < 0$: the optimal subsidy is decreasing in δ_i, as misperception falls the size of the subsidy decreases.

Note that (52) implies

$$\bar{\mathrm{x}}\varepsilon_{\bar{\mathrm{x}},s} = \int_{y_l}^{y_h} (1-\delta_i) b'(\chi_\iota) \frac{\partial \chi_i}{\partial s} \mathrm{dF(y)} \tag{53}$$

That is, at the optimum, the average consumption weighted by its subsidy elasticity is equal to the average marginal internality weighted by the subsidy effect on demand.

Equation (52) can be rewritten as

$$s^* = E[(1-\delta_i) b'(x_i)] + \frac{Cov\left[(1-\delta_i) b'(x_i),\ \frac{\partial x_i}{\partial s}\right]}{\frac{\partial \bar{x}}{\partial s}} \tag{54}$$

The analysis of equation (54) is equivalent to the one for the tax (equation (26)). The first term of equation (54) is positive and reflects the average overlooked marginal internal benefit by the healthy good consumption. The second, adjustment, term is based on the covariance of the overlooked marginal internal benefit and the consumer's response to the subsidy. The sign of the second term depends on the sign of $Cov\left[(1-\delta_i)b'(x_i),\ \frac{\partial x_i}{\partial s}\right]$ since $\frac{\partial \bar{x}}{\partial s}$ is positive.

Note $(1-\delta_i)b'(x_i)$ decreases, as δ_i increases and hence x_i increases, since both $(1-\delta_i)$ and $b'(x_i)$ decrease (given $b''(x_i) < 0$). On the other hand, an increase in δ_i leads to an increase in $\frac{\partial x_i}{\partial s}$ as $\frac{\partial^2 \chi_i}{\partial s \partial \delta_i} > 0$. Thus, a change in δ_i affects $(1-\delta_i)b'(x_i)$ and $\frac{\partial x_i}{\partial s}$ in opposite directions, and

$$Cov\left[(1-\delta_i)b'(\chi_i),\ \frac{\partial \chi_i}{\partial s}\right] < 0$$

The second term in (54) is negative and the optimal subsidy is less than the average internality (assuming prudence and DARA). This is because the subsidy has a lower impact on consumers with higher misperception.

Result 5:

(i) The second-best Pigouvian tax is equal to the weighted average of individual misperception regarding marginal harm.
(ii) The second-best Pigouvian subsidy is equal to the weighted average of individual marginal misperception regarding the healthy good.
(iii) The optimal tax on unhealthy consumption is higher than the average misperception internality.
(iv) The optimal subsidy on healthy consumption is lower than the average misperception internality.

Given that low-income individuals, relative to high-income ones, consume more of the unhealthy good (hence, pay relatively more on taxes) and less of the healthy good (hence, receive relatively less as subsidy), the tax-subsidy scheme is likely to be more regressive than a simple fat tax with a lump sum transfer. However, from the health side, a subsidy is more progressive than a lump-sum transfer. Individuals benefit not only from the reduction in unhealthy good consumption but also from the increase in healthy good consumption. This is because of the assumption that misperception is decreasing in income.

Finally, comparing sections 7.3.1 and 7.4.1, it turns out that the optimal tax rate is not affected by the use of the revenue it collects. Hence,

Result 6: *When only efficiency matters, earmarking the fat tax to finance a thin subsidy does not affect the optimal tax rate.*

7.4.2 Corrective Taxes and Subsidies with Redistributive Motives

As already mentioned in Section 7.3.2, when government has distributional concerns, utility from the numeraire good is $v(c_i)$, with $v'(c_i) > 0$ and $v''(c_i) < 0$. The negative second derivative means that an additional unit of money given to low-income individuals is worth more than a unit given to high-income people. When distributional concerns are present and government sets a tax on the unhealthy good and a subsidy on the healthy good, the individual maximization problem is

$$\max_{c_i, x_i, \varphi_i} \hat{U}_i = v(c_i) + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i)$$

$$\text{s.t } y_i = c_i + (1-s)x_i + (1+t)\varphi_i$$

The Langrangean for this problem is then

$$L = v(c_i) + \delta_i b(x_i) + v(\varphi_i) - \beta_i h(\varphi_i) - \lambda_i[c_i + (1-s)x_i + (1+t)\varphi_i - y_i] \quad (55)$$

The FOCs are

$$\frac{\partial \hat{U}_i}{\partial x_i} = \delta_i b'(x_i) - \lambda_i(1-s) = 0 \quad (56)$$

$$\frac{\partial \hat{U}_i}{\partial \varphi_i} = v'(\varphi_\iota) - \beta_i h'(\varphi_i) - \lambda_i(1+t) = 0 \quad (57{\equiv}29)$$

and $\lambda_i = v'(c_i) > 0$.

The comparative statics with respect to misperception, tax and subsidy are given by

$$\frac{\partial x_i^*}{\partial s} = -\frac{\lambda_i}{\delta_i b''(x_i)} > 0 \quad (58)$$

$$\frac{\partial \varphi_i^*}{\partial t} = \frac{\lambda_i}{v''(\varphi_\iota) - \beta_i h''(\varphi_i)} < 0 \quad (59{\equiv}(31)$$

$$\frac{\partial x_i}{\partial \delta_i} = -\frac{b'(x_i)}{\delta_i b''(x_i)} = b'(x_i)\frac{1}{\lambda_i}\frac{\partial x_i}{\partial s} > 0 \quad (60)$$

$$\frac{\partial \varphi_i^*}{\partial \beta_i} = \frac{h'(\varphi_i)}{\upsilon''(\varphi_\iota) - \beta_i h''(\varphi_i)} = h'(\varphi_i)\frac{1}{\lambda_i}\frac{\partial \varphi_i^*}{\partial t} < 0 \qquad (61\equiv(32)$$

$$\frac{\partial^2 x_i}{\partial s \partial \delta_i} = \lambda_i \frac{b''(x_i) + \delta_i b'''(x_i)\frac{\partial x_i}{\partial \delta_i}}{[\delta_i b''(x_i)]^2} \qquad (62)$$

$$\frac{\partial^2 \varphi_i^*}{\partial t \partial \beta_i} = \lambda_i \frac{-[\upsilon'''(\varphi_\iota) - \beta_i h'''(\varphi_i)]\frac{\partial \varphi_i}{\partial \beta_i} + h''(\varphi_i)}{[\upsilon''(\varphi_\iota) - \beta_i h''(\varphi_i)]^2} \qquad (63\equiv(33)$$

Since (57) is the same as (29), the comparative statics given by (61) and (63) will be the same as (32) and (33), respectively. Also, (58) and (62) are the same as (40) and (44), respectively, multiplied by λ_i. $\frac{\partial^2 x_i}{\partial s \partial \delta_i}$ is assumed to be positive and the explanation is the same as for (44), since $\lambda_i > 0$.

The government solves

$$\max_t W = \int_{y_l}^{y_h} \{\upsilon(c_i) + b(x_i) + \upsilon(\varphi_i) - h(\varphi_i)$$
$$- \lambda_i[c_i + (1-s)x_i + (1+t)\varphi_i - y_i]\} \, dF(y) - \mu(s\bar{x} - t\bar{\varphi}) \qquad (64)$$

Then,

$$\frac{\partial W}{\partial t} = \int_{y_l}^{y_h} \left\{[\upsilon'(\varphi_i) - h'(\varphi_I) - \lambda_i (1+t)]\frac{\partial \varphi_i}{\partial t} - \lambda_i \varphi_i\right\} dF(y) + \mu(\bar{\varphi} + t\frac{\partial \bar{\varphi}}{\partial t})$$

$$= \int_{y_l}^{y_h} \left\{[-(1-\beta_i)h'(\varphi_i^*)]\frac{\partial \varphi_i}{\partial t} - (\lambda_i - \mu)\varphi_i\right\} dF(y) + \mu t \frac{\partial \bar{\varphi}}{\partial t} = 0 \qquad (65)$$

and the optimal tax is

$$t^* = \frac{1}{\mu}\left[\frac{\int_{y_l}^{y_h}(1-\beta_i)h'(\varphi_i)\frac{\partial \varphi_i}{\partial t} dF(y)}{\frac{\partial \bar{\varphi}}{\partial t}} + \frac{\int_{y_l}^{y_h}(\lambda_i - \mu)\varphi_i dF(y)}{\frac{\partial \bar{\varphi}}{\partial t}}\right] \qquad (66)$$

If $\lambda_i = \mu$, there are no distributional concerns and (66) reduces to (49). The marginal utility of income is equal to the marginal value of government revenue and only efficiency matters.

If $\lambda_i > \mu$, that is, individual marginal utility of income is higher that the marginal value of government revenue, the optimal tax is regressive and its rate falls relative to (49). The opposite holds, if $\lambda_i < \mu$.

Differentiating (64) with respect to s, we get

$$\frac{\partial W}{\partial s} = \int [b'(x_i) - \lambda_i(1-s)] \frac{\partial x_i}{\partial s} \mathrm{dF(y)} + \int \lambda_i x_i \, \mathrm{dF(y)} - \mu\left(\bar{x} + s\frac{\partial \bar{x}}{\partial \mathrm{s}}\right) = \tag{67}$$

$$= \int (1-\delta_i) b'(x_i) \frac{\partial x_i}{\partial s} \mathrm{dF(y)} + \int (\lambda_i - \mu) x_i \, \mathrm{dF(y)} - \mu s \frac{\partial \bar{x}}{\partial s} = 0$$

The optimal subsidy is then

$$s^* = \frac{1}{\mu}\left[\frac{\int (1-\delta_i) b'(x_i) \frac{\partial x_i}{\partial s} \mathrm{dF(y)}}{\frac{\partial \bar{x}}{\partial s}} + \frac{\int (\lambda_i - \mu) x_i \, \mathrm{dF(y)}}{\frac{\partial \bar{x}}{\partial s}}\right] \tag{68}$$

Again, if $\lambda_i = \mu$, there are no distributional concerns and (68) reduces to (52). If $\lambda_i > \mu$, the optimal subsidy is progressive and its rate increases relative to (52). The opposite holds, if $\lambda_i < \mu$.

In section 7.2 , we showed that low-income individuals consume more of the unhealthy good and less of the healthy one relatively to high-income individuals. In presence of distributional concerns, the second-best optimal tax and subsidy scheme is a trade-off between efficiency and equity.

Result 7: *Since low-income individuals (those with $\lambda_i > \mu$) consume more of the unhealthy good and less of the healthy one relatively to high-income individuals, the optimal tax rate is lower and the optimal subsidy higher relative to the case of no distributional concerns.*

When the fiscal policy is purely corrective, optimal tax and subsidy are higher and lower, respectively, than the average internality. The presence of distributional concerns lowers the tax and increases the subsidy rate, bringing them closer to the average corresponding internality. Hence, the scheme is less income regressive. As regards the impact on health, it is difficult to reach a conclusion as individuals will consume more of both goods compared to the corresponding scheme with no distributional concerns. Since $h''(\varphi_i) > 0$ and $b''(x_i) < 0$, the unhealthy good consumption has a greater impact on health. Based on that, if we put more weight on unhealthy good consumption, this scheme is more likely to be less health progressive.

Result 8:

When distributional concerns are present, the combination of tax and subsidy is less income regressive, but it might be also less health progressive.

7.5 Conclusions

The purpose of this chapter is to examine the optimal tax on unhealthy goods and whether it depends on whether a) the tax revenue is earmarked for subsidization of a healthy good and b) there are distributional concerns. The analysis is based on the model developed by Cremer et al. (2016), where individuals differ in income and the degree of misperception regarding the benefits and the costs arising from the consumption of a healthy and an unhealthy good, respectively. In the presence of misperceptions, individuals move away from the optimal consumption, consuming higher quantities of the unhealthy good and lower quantities of the healthy one.

Assuming prudence and DARA, we show that the tax effect on unhealthy good consumption is greater for low-income individuals (i.e., the targeted group[39]) than for high-income ones. The opposite occurs for the subsidy effect on healthy good consumption. Thus, if government has to choose between a tax on unhealthy good and a subsidy on healthy good, the tax is a more effective measure to improve health.

Having tax as the base policy, we analyse four scenarios where schemes of revenue use and distribution concerns differ. In the first scenario (Section 7.3.1), tax revenue is returned to individuals via a lump-sum transfer, in the absence of distributional concerns. The purely corrective optimal tax is the weighted average of individual misperceptions regarding marginal harm and, assuming prudence, it is higher (ceteris paribus) than the average internality misperception. Since low-income individuals consume relatively more of the unhealthy good, the tax is regressive. However, the health benefits are expected to be higher for them than those of high-income individuals.[40] Thus, the tax might be income-regressive but it is health-progressive. When distributional concerns are added (Section 7.3.2), the optimal tax is lower relatively to the case of no distributional concerns. Moreover, the lump sum transfer is higher for low-income individuals. Thus, this tax scheme is less income regressive but also less heath progressive.

[39] Low-income individuals are the targeted group as they consume more of the unhealthy good and less of the healthy good.

[40] Assuming $\frac{\partial^2 \varphi_i}{\partial t \partial \beta_i} > 0$.

For the other two scenarios, we assume that revenue is used to finance a subsidy on the healthy good. When government has no distributional concerns (Section 7.4.1), the optimal tax on unhealthy consumption is the same regardless of the selected revenue use schemes. As regards the subsidy, this is equal to the weighted average of individual marginal misperception regarding the healthy good and it is lower than the average internality misperception. Compared to the first scenario, this scheme might be more regressive, although the tax rate is the same. This occurs because low-income individuals consume less of the healthy good and the subsidy received might be lower than the lump sum transfer. However, the subsidy is a complementary policy which contributes to the health improvement. Thus, it is more health progressive. On the other hand, when redistribution concerns exist (Section 7.4.2), the optimal tax is lower and the optimal subsidy higher relatively to the case of no distributional concerns, making it a less regressive scheme but likely a less health progressive scheme.

Based on above, when health is the priority, the most appropriate scheme is to combine the tax with a subsidy in the absence of distributional concerns (the third scenario). On the other hand, if government wants to protect low-income individuals, implementing the less income regressive scheme, then it should choose between the two scenarios with distributional concerns (second and forth scenarios). Because the tax rates are not comparable, it is difficult to reach a conclusion. Intuitively, as low-income individuals consume more of the unhealthy good and less of the healthy good, it is more likely the amount of tax being greater than the subsidy received. On the other hand, with the appropriate redistribution, a low-income individual is likely to receive a lump sum transfer higher than the amount paid on tax. Thus, the second scenario might be even income progressive. If government does not want to implement one of the two extreme policies, the fourth scenario might be an intermediate solution. The distribution concerns lower the tax rate but tax revenue is used to finance a subsidy on healthy good which contributes to health improvement.

This study confirms and extends findings of other studies (Cremer et al., 2016; Griffith et al., 2018; Haavio and Kotakorpi, 2011). However, as every study, it has its limitations. We mention two main limitations. The study is based on a perfectly competitive environment where tax and subsidy are fully passed on to consumers. Results might change when firm's strategic behaviour is taken into account. Also, this study does not take into account substitution effects, which might enhance or reduce the tax and/or subsidy effects.

Chapter 8: Price Elasticities of Food and Beverages and the Potential for Fiscal Policies to Improve Eating Habits and Combat Obesity in Greece

8.1 Introduction

Obesity is a near worldwide problem that has almost tripled in prevalence since 1975. The problem is even greater for children and adolescents. The prevalence of overweight and obesity at the ages of 5-19 years has increased more than four times since 1975 (WHO, 2020). This trend is also followed in Greece, with prevalence of obesity reaching around 25% for adults and 14% for children and adolescents in 2016. Taking into account the overweight population, these proportions increase to 62.3% and 37.3%, respectively, ranking Greece first and third in terms of childhood and adult overweight rates among the 27 EU countries (WHO, 2017a).

Obesity has a number of health and financial consequences. Obese people are more likely to develop a number of chronic diseases, such as cardiovascular diseases, respiratory diseases, cancer, type 2 diabetes and musculoskeletal disorders (CDC, 2020), as well as psychological problems (Sarwer and Polonsky, 2016). These obesity-related diseases have financial consequences as they are related to high healthcare expenditures, imposing a burden on the health system. Also, they might lead to disability and premature death, creating productivity losses. As shown in Section 3.1, the estimated total cost of overweight and obesity, in Greece, was € 335.09 per capita (2% of GDP) for 2017, and increased by 12.68% in a twenty-year period.

The need for policies to combat the obesity epidemic in Greece is clear. The great increase in obesity rates is linked with the change in dietary habits, which are steadily moving away from the Mediterranean diet and towards more sugary and fat foods (for more details, see Section 1.1.1). In this Chapter, I study the effects of simulated fiscal policies used to steer food consumption away from unhealthy options and towards healthier ones in Greece.

Specifically, the aim of this chapter is: (a) to estimate own and cross-price elasticities for thirteen food categories, so as to provide policymakers with a useful tool for fiscal policies on diet; and (b) to estimate the effect of different tax and subsidy scenarios on food demand for the examined categories. The policy scenarios are the following: (i) a 20% tax on soft drinks and juices, including unsweetened beverages and carbonated water; (ii) a 20% tax on sweets (e.g. sugar, jams, chocolate, ice cream and confectionery products); (iii) a 19.35% subsidy on fruits and vegetables, which is equivalent to zero-rating from the current 24% value-added tax; and (iv) a combined tax and subsidy policy (combination of the three first scenarios).The first policy scenario was chosen based on the WHO recommendations that sugar sweetened beverages (SSBs) should be taxed by at least 20% (WHO, 2016b). On top of that, I followed the example of countries, such as Finland, where unsweetened beverages and carbonated water are included in the taxed products. As regards the subsidy policy, it is based on a recent request to the European Council to consider a zero VAT tax on fruits and vegetables (Foodwatch, 2021). This subsidy rate is also within the range of 10% - 30% which is considered effective based on a meta-review of eleven systematic reviews (WHO, 2016b).

Existing studies estimating food price elasticities in Greece (Andrikopoulos et al., 1987; Demoussis, 1985; Karagiannis and Velentzas, 1997; Karagiannis, 2002; Klonaris and Hallam, 2003; Kostakis et al., 2020; Mantzouneas et al., 2004; Mergos and Donatos, 1989; Rigas, 1987) use much older data and more general or less categories. Moreover, there are no published studies on the effects of fat taxes and thin subsidies on food consumption.

The chapter is organized as follows. In Section 8.2, a literature view on previous estimates of price elasticities for Greece takes place. In Section 8.3, I discuss the method used and, in Section 8.4, the data and their sources. In Section 8.5, the results of this study are presented. Finally, in Section 8.7, the findings and conclusions are discussed.

8.2 Literature review

To the best of our knowledge, there is no study examining simulated effects of fat taxes and/or thin subsidies on food consumption, in Greece. However, there are some studies estimating price elasticities for different food categories (Andrikopoulos et al., 1987; Demoussis, 1985; Karagiannis and Velentzas, 1997; Karagiannis, 2002; Klonaris and Hallam, 2003; Kostakis et al., 2020; Mantzouneas et al., 2004; Mergos and Donatos, 1989; Rigas, 1987). Except of Kostakis et al. (2020), all studies use time-series data from the National Accounts of Greece for a long time period (about 30-40 years) belonging to time interval between 1950 and 1995. The majority of these studies use the Almost Ideal Demand System (AIDS) model. Specifically, Rigas (1987) and Mergos and Donatos (1989) use the classic static AIDS model developed by Deaton and Muellbauer (1980). Other studies (Karagiannis and Velentzas, 1997; Karagiannis, 2002; Klonaris and Hallam, 2003; Mantzouneas et al., 2004) use dynamic versions of the AIDS model, incorporating habit formation. The dynamic AIDS models of Karagiannis and Velentzas (1997) and Mantzouneas et al. (2004) are also based on the Error Correction Model. On the other hand, Demoussis (1985) and Mantzouneas et al. (2004) estimate price elasticities with different approaches, which are the Habit Linear Expenditure System (LES) and the Rotterdam approach, respectively.

In these studies, price elasticities were estimated for various food categories. Excluding Klonaris and Hallam (2003) and Kostakis et al. (2020), the studies include six common food categories, which are: (1) bread and cereals; (2) meat; (3) milk, cheese and eggs; (4) oils and fats; (5) fruits and vegetables; and (6) other food items. Other categories included in their analysis are fish (Andrikopoulos et al., 1987; Demoussis, 1985; Karagiannis and Velentzas, 1997; Karagiannis, 2002; Rigas, 1987), alcoholic and non-alcoholic beverages (Andrikopoulos et al., 1987), tobacco (Andrikopoulos et al., 1987) and non-food (Andrikopoulos et al., 1987; Demoussis, 1985; Mergos and Donatos, 1989).

All but Mantzouneas et al. (2004) have estimated both own- and cross-price elasticities. Results differ based on the methodological approach. Karagiannis and Velentzas (1997) estimated Hicksian price elasticities and, as expected, these are lower than Marshallian elasticities estimated in other studies. Also, results from Rotterdam and AIDS models are closer compared to LES, as both of them consist of more flexible functional forms. Mantzouneas et al. (2004) show that the selected time period is also crucial. They estimated own-price elasticities for three time periods (1965–1975, 1976–1985 and 1986–1995): for some food categories own-price elasticities changed over time with demand for (i) bread and cereals and (ii) oils and fats becoming more price-inelastic and demand for meat becoming more price-elastic.

In these studies, the expenditure (income) elasticity is also estimated. Based on their results, all products are normal goods (positive expenditure elasticity), with the only exception being bread and cereals in some studies (Demoussis, 1985; Mergos and Donatos, 1989; Rigas, 1987). Estimates by Rigas (1987) and Karagiannis and Velentzas (1997) give expenditure elasticities greater than one for most of good categories. Vegetables and fruits, meat and non-food are the categories with expenditure elasticity greater than one in the majority of the mentioned studies.

A study that differs from the others is that by Klonaris and Hallam (2003), in which both conditional[41] and unconditional demand elasticities are estimated, in a three stage analysis using a dynamic AIDS model. In the first stage, there is one food category along with other seven non-food categories. In the

[41] A typical assumption in demand analysis is weak separability which leads to conditional demand elasticities.

second stage, the food category splits into three sub-categories (beverages and tobacco, animalia, and various food). In the final stage, there is further separation of the food categories. The three subgroups of beverages and tobacco are non-alcoholic beverages, alcoholic beverages and tobacco; the three subgroups of animalia are meat, fish and dairy products; and the four subgroups of various food are bread and cereals, oils and fats, fruits and vegetables and miscellaneous. Own-price elasticities are estimated for all categories, while cross-price elasticities are estimated only for the categories belonging to the same group. In stage 3, for all categories, conditional and unconditional price elasticities are less than one and the goods are normal. Meat, fruits and vegetables, non-beverages, tobacco and miscellaneous are found to be luxury goods.

The most recent study is Kostakis et al. (2020), who estimate price elasticities with three different methods, using data from 2016. Using the Generalized Linear Model and the Deaton (1988) method, they estimated own-price elasticities for the following food categories: (1) bread and cereals; (2) meat; (3) sea and seafood; (4) milk, cheese and eggs; (5) oils and fats; (6) fruits; (7) vegetables; (8) sugar, jam, honey, chocolate and confectionary; (9) coffee, tea and cocoa; (10) wine; and (11) beer. Using the Quadratic AIDS (QAIDS) model, both own- and cross-price elasticities are estimated for the four food categories with the highest budget shares (i.e., bread and cereals; meat; milk, cheese and eggs; and vegetables). Results from all three methods show that only demand for milk, cheese and eggs is price-elastic. As regards cross-price elasticities estimated by QAIDS, the great majority of goods are complements. Only "milk, cheese and eggs" is substitute for meat and vegetables, and vice versa. Also, all goods are normal, with meat and sugar[42] being the only luxury goods.

8.3 Method

In order to estimate price elasticities of demand, the required data are market prices and quantities sold. For some countries, however, these data are poor or do not even exist. The solution to this problem comes from Deaton (2019, 1990, 1988), who developed the unit value model based on which price elasticities could be estimated using household survey data.

Knowing the expenditure and quantity for each good i purchased by household h, it is easy to calculate a proxy for prices, the unit value, as follows:

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[42] Sugar is a luxury good only when the Deaton (1988) method is used.

$$V_{ih} = \frac{E_{ih}}{Q_{ih}} \tag{1}$$

where V_{ih} is the unit value, E_{ih} is expenditure and Q_{ih} is quantity of good i for household h. The calculated unit values are affected by the actual prices, λ_{i}, but also by the choice of quality, v_{i}. That is

$$V_{ih} = \lambda_i v_{ih} \tag{2}$$

High-quality items will have higher unit values. For example, a kilo of stewing beef costs much less than a kilo of the best steak. This occurs even for relatively homogeneous goods (e.g., rice) as there might be many types and grades (Deaton, 2019).

In this study, we work not with single items but with groups of goods. In this case, the unit value for each group, g, which consists of j sub items, is calculated using a Laspeyers-type index, as follows:

$$V_{gh} = \sum_{i=1}^{j_g} s_{gih} V_{gih} \tag{3}$$

where, V_{gh} is the unit value of group g, V_{gih} is the unit value of sub item i and s_{gih} is the weight of sub item i calculated as the ratio of expenditure on sub item i to total expenditure on group g for household h. For households reporting zero consumption on all sub items of a group, the unit value faced is the average unit value of that group at the cluster level to which it belongs (Araar et al., 2018).

Also, instead of quantities, Deaton (1988 and 1990) use budget shares, calculated as:

$$w_{gh} = \frac{E_{gh}}{TE_h} \tag{4}$$

where w_{gh} is the budget share of group g and TE_h is total expenditure on all goods and services purchased by household h. Using budget shares, instead of quantities,[43] allows as to include also households with zero consumption, which is vital for tax reform purposes.

A key assumption is that households located at the same geographical area are clustered within the sample and face the same market prices while unit values vary spatially. Thus, before we continue with the model, it is important to examine whether this assumption is satisfied. In this context, an

[43] Deaton (1987) uses double-logarithmic demand equations. Thus, based on this model, households with zero consumption have to be excluded.

Analysis of Variance (ANOVA) is used to divide the total variation in unit values into "within-cluster variations" and "between-cluster variations."

If the assumption of spatial variation of unit values holds, we are allowed to continue with the unit value model which is specified as follows:

$$w_{ghc} = a_g^0 + \beta_g^0 lnx_{hc} + \gamma_g^0 z_{hc} + \sum_{i=1}^{N} \theta_{gi} lnp_{ic} + (f_{gc} + u_{ghc}^0) \quad (5)$$

$$lnV_{ghc} = a_g^1 + \beta_g^1 lnx_{hc} + \gamma_g^1 z_{hc} + \sum_{i=1}^{N} \psi_{gi} lnp_{ic} + u_{ghc}^1 \quad (6)$$

where $\boldsymbol{w_{ghc}}$ and $\boldsymbol{V_{ghc}}$ are the budget share and unit value[44] of good g for household h in cluster c, respectively;. $\boldsymbol{x_{hc}}$ is per capita household expenditure for household h in cluster c; $\boldsymbol{p_{ic}}$ is the market price for each of *N* goods in cluster c; $\boldsymbol{z_{hc}}$ is a vector of households characteristics, including the gender, age and the level of education of the head of household. Other household characteristics are the proportion of household members with their own income and the proportion of household members who are considered dependents (i.e., members under the age of 18 or between 18 and 24, providing they are still students). $\boldsymbol{f_{gc}}$ is a cluster fixed effect which represents unobservable taste variation from cluster to cluster, while $\boldsymbol{u_{ghc}^0}$ and $\boldsymbol{u_{ghc}^1}$ are the standard error terms.

Note that prices, p_{ic}, and fix effects, f_{gc}, are unknown. As a result, the coefficients of equations (5) and (6) could not be estimated directly and a two-stage estimation technique is followed. At the first stage, within-cluster information[45] is used and the parameters β_g^0, β_g^1, γ_g^0 and γ_g^1 of equations (5) and (6) are estimated by "within-cluster" OLS, removing cluster means from the data. This method subtracts the unknown fix effects, as well as the unobserved prices, and gives the within cluster estimates $\tilde{\beta}_g^0$, $\tilde{\beta}_g^1$, $\tilde{\gamma}_g^0$ and $\tilde{\gamma}_g^1$.

The coefficient β_g^1, in the "unit value" equation (6), shows the relationship between household expenditure and unit value and is the *expenditure elasticity of quality*. If β_g^1 is statistically significant and positive, quality effects exist and they are taken into account to correct final price elasticities for quality shading. The existence of a positive expenditure elasticity of quality indicates that, although

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[44] "Unit value" equation (Equation (5)) is used to examine the presence of quality effects in the unit values.
[45] i.e prices do not vary within cluster.

all households in the same geographical area face the same market prices, unit values will be higher for better-off households, mainly because they tend to buy higher-quality goods.

At the second stage, between-cluster information is used to estimate the price elasticities. Specifically, the estimated coefficients from the first stage are used to "correct" the shares and unit values by calculating the following variables which are averaged by cluster:

$$\tilde{y}_{1gc} = w_{gc} - \tilde{\beta}_g^0 lnx_c - \tilde{\gamma}_g^0 z_c \tag{7}$$

$$\tilde{y}_{2gc} = lnV_{gc} - \tilde{\beta}_g^1 lnx_c - \tilde{\gamma}_g^1 z_c \tag{8}$$

From equations (5) and (6), the true values of y_{1gc} and y_{2gc} can be written as:

$$y_{1gc} = \quad a_g^0 + \sum_{i=1}^{N} \theta_{gi} lnp_{ic} + \left(f_{gc} + u_{gc}^0\right) \tag{9}$$

$$y_{2gc} = \quad a_g^1 + \sum_{i=1}^{N} \psi_{gi} lnp_{ic} + u_{gc}^1 \tag{10}$$

The estimated variables, $\tilde{y}_{1gc}$ and $\tilde{y}_{2gc}$, are used to estimate the variance –covariance matrix of $\mathrm{y}_1{}'s$ as well as the covariance matrix of $\mathrm{y}_1{}'s$ with the $\mathrm{y}_2{}'s$. These estimates do not give direct estimations of matrices Ψ and Θ but the "mixed" matrix $B = (\Psi')^{-1}\Theta'$.

As it is shown in Deaton (1988) and extended in Deaton (1990),

$$\psi_{gi} = \delta_{gi} + \beta_g^1 \frac{\varepsilon_{gi}}{\varepsilon_x} \tag{11}$$

where $\boldsymbol{\varepsilon_{gi}}$ is the price elasticity and $\boldsymbol{\delta_{gi}}$ is the Kronecker delta which equals one when $i = g$ and zero otherwise. Combining equation (11) with matrix B allows us to estimate θ_{gi}.

Having estimated the coefficients θ_{gi} and ψ_{gi}, own and cross price elasticities are estimated as follows:

$$\varepsilon_{gi} = -\psi_{gi} + \frac{\theta_{gi}}{w_g} \tag{12}$$

Finally, we are interested in estimating the expenditure elasticity of quantity, $\boldsymbol{\varepsilon_x}$, using the following formula:

$$\varepsilon_x = \left(1 - \beta_g^1\right) + \frac{\beta_g^0}{w_g} \tag{13}$$

which is easily computed taking the log of budget share (equation (3)) and differentiating with respect to total expenditure.

Because the own and cross price elasticities, as well as the expenditure elasticity of quantity, were not estimated directly, standard errors were estimated using the bootstrap method, chosen to make 1,000 replications. In each replication, a sample with replacement is drawn with the same size as the original sample. Each time, elasticities are recalculated and then used to find (half) the length of interval around the bootstrapped mean that contains 68.3%[46] of the bootstrapped estimates. Estimates are statistically significant at the 5% level if they are greater (in absolute value) than approximately twice their bootstrapped standard errors.

The goods of interest are classified into thirteen different food categories: (1) bread, cereals and flour, (2) potatoes, pasta and rice, (3) meat, (4) fish and seafood, (5) milk products (milk, cheese and yogurt) and eggs, (6) vegetable oils and fats, (7) fruits, (8) vegetables, (9) sweets (10) soft drinks, juices and water, (11) coffee and tea, (12) alcoholic drinks, (13) other unhealthy goods. The food categories with their sub items are listed in Table A.5.1, in Appendix A.5.

Price elasticities were estimated taking into account the quality effect and also imposing the symmetry restriction. An argument in favor of symmetry restriction is that there is not always a great deal of price variation (Deaton, 2019).

Last but not least, the price elasticities were used to simulate the effects of examined taxes and subsidies on all thirteen good categories. As in Thiele (2010), the percentage change in demand for food category g (%ΔQ) due to the tax and/or subsidy on selected goods can be calculated as follows:

$$\%\Delta Q_g = \sum_{i=1}^{n} \varepsilon_{gi} \%\Delta p_i \tag{14}$$

where, ε_{gi} is the cross-price elasticity of demand for good category g with respect to the price of good category i and $\%\Delta p_i$ is the percentage change in price for food category i. n is equal to thirteen as the number of good categories.

For the above estimates, the 16.1 STATA software and the WELCOM Stata tool were used (Araar et al., 2018).

[46] The fraction of a normal random variable within two standard deviations of the mean.

8.4 Data and Data Sources

The data used come from the Greek Household Budget Survey (HBS), carried out in 2019 (ELSTAT, 2020). HBS is conducted annually by the Hellenic Statistical Authority and covers completely the reference population with a representative sample. The final sample of the 2019 HBS was 6,150 households, divided into 72 strata based on their geographical location and the degree of urbanization. The collection of research data took place during the period January-December 2019 and strata were evenly distributed throughout the year, in order to select four equivalent independent samples, corresponding to the four quarters of the year.

For each household, the total duration of the survey was fourteen continuous days. During this period, each selected household had to complete a questionnaire about its composition, living conditions and members' employment status, as well as information about members' expenditure on goods and services and their income.

Household expenditures (and quantities) were reported analytically and were divided into twelve major categories. In this study, the interest is focused on only two categories, "Food and non-alcoholic beverages" and "Alcoholic beverages and tobacco". The reported data were published after having been converted to annual data and the quantities were reported in kilos, litre or items, depending on the type of good. However, Deaton's method requires that the quantity of all goods should be at the same unit of measurement. For that reason, liquids, such as oil and milk, were converted to kilos using density units for conversion by the Food and Agriculture Organization of the United Nations (Charrondiere et al., 2012). Also, eggs, which were reported in items, were converted to kilos using a conversion factor of 58 grams per egg.[47] The conversion factors for liquids are shown in Table A.5.2, in Appendix A.5.

Table 8.1 reports summary statistics for the variables used in our model and for some extra variables related to expenditure and income. On average, household expenditure on purchase is €17,204.50, which corresponds to €7,423.94 per member. Taking into account expenditure in non-monetary form (e.g., from own production), total expenditure is €21,497.70 and €9,525.22, respectively. Comparing expenditure with income, it is clear that, on average, the household spends almost all its income (about 95%) to buy goods and services.

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[47] It is the average weight of the most sold category, the medium size, which varies from 53 to 63 grams.

Table 8.1: Summary statistics from the 2019 Household Budget Survey, Greece

Variables	*Unweighted*	*Weighted*
Expenditure		
Av. household expenditure on purchase	15,374.37	17,204.50
Av. per capita expenditure on purchase	7,322.22	7,423.94
Av. household total expenditure(1)	19,561.49	21,497.70
Av. per capita total expenditure(1)	9,571.02	9,525.22
Income		
Av. household monetary income	16,577.66	17,823.55
Av. per capita monetary income	7,964.16	7,752.99
Av. household total income(2)	20,447.91	21,814.10
Av. per capita total income(2)	10,073.26	9,735.97
Members of household		
Av. Number of members	2.26	2.55
Av. Proportion of members with income	79.51%	75.97%
Av. Proportion of dependent members	11.30%	14.88%
Head of household		
Av. age of household head in years	60.94	57.38
Proportion of male heads	67.77%	68.82%
Educational level of household head		
Early childhood education	9.27%	6.96%
Complete primary education	25.49%	21.10%
Complete lower secondary education	8.84%	8.86%
Upper secondary education(3)	25.21%	27.52%
Post-secondary non tertiary education(3)	5.83%	6.38%
Short cycle tertiary, Bachelor or equivalent(3)	22.12%	25.09%
Higher level of education	3.24%	4.09%
Region		
Densely populated areas	37.57%	43.75%
Mid density regions	31.04%	31.46%
Sparsely populated areas	31.39%	24.79%

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020)
Notes: (1) with all modes of acquisition (i.e., monetary and non-monetary form); (2) from all sources (i.e., including both monetary and non-monetary components); (3) including also incomplete education.

A large proportion of households (43.75%) are located in densely populated areas. The average household consists of 2.55 members. About three out of four members have their own income while only a small proportion are dependent members (14.88%). Regarding the head of the household, the average age is 57.4 years, 68.82% of them are males and 29.18% have tertiary education (see Table 8.1).

8.5 Estimation Results

All selected goods account for 25.63% of household total budged share. The categories with higher mean budget shares are "meat" (4.58%), "milk products & eggs (4.00%)" and "bread, cereals and flour (3.25%)". On the contrary, "soft drinks, juices and water", "coffee and tea" and "alcoholic drinks" have the lowest average budget shares (0.65%, 0.66% and 0.99%, respectively). "Coffee and tea" has the highest mean unit value (€25.80) by far, while the lowest unit value (€1.10) is observed in "Soft drinks, juices and water" (see Table 8.2).

Table 8.2: Mean of budget share and unit values for each category

Category	*% of hh with non-zero expenditure*	*Budget share (weighted mean)*	*Unit value (weighted mean)*
Bread, cereals and flour	98.58%	3.25%	4.67
Potatoes, pasta and rice	92.77%	1.17%	1.63
Meat	91.73%	4.58%	6.89
Fish and seafood	67.10%	1.50%	8.97
Milk products and eggs	97.82%	4.00%	4.31
Vegetable oils and fats	71.81%	1.46%	4.58
Fruits	93.58%	1.61%	1.25
Vegetables	95.91%	2.82%	2.27
Sweets	75.37%	1.18%	9.39
Soft drinks, juices and water	68.75%	0.65%	1.10
Coffee and tea	69.77%	0.66%	25.80
Alcoholic drinks	45.37%	0.99%	10.28
Other unhealthy goods	79.35%	1.38%	10.28

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020).
Note: The weighted means of budget shares and unit values are calculated based on sample weights which take into account: a) the probability of household's selection into the sample, b) the response rate of households, and c) known population characteristics.

The second column in Table 8.2 shows the proportion of households recording non-zero expenditure. For six categories,[48] this proportion exceeds 90%. The only category with a low number of observations is "alcoholic drinks" as only 45.37% of households report positive consumption.

The results of ANOVA, which tests the assumption of prices' spatial variation, are shown in Table 8.3. For each category, the p-value associated with the F statistic is very small (0.000). Thus, the null hypothesis of no spatial variation is rejected. However, for some categories the proportion of total variation in unit values explained by cluster effects, given by R-squared, is small. Specifically, for categories "potatoes, pasta and rice", "milk products and eggs", "fruits" and "vegetables", R-squared is less than 20%. On contrary, R-squared for "fish and seafood" and "other unhealthy goods" is 69.65% and 67.20%, respectively.

Table 8.3: ANOVA test for spatial variation

Category	*F statistic*	*R-squared*
Bread, cereals and flour	41.25	0.3453
Potatoes, pasta and rice	18.03	0.1873
Meat	38.14	0.3278
Fish and seafood	179.53	0.6965
Milk products and eggs	11.33	0.1266
Vegetable oils and fats	33.53	0.3000
Fruits	7.54	0.0880
Vegetables	18.16	0.1884
Sweets	90.33	0.5359
Soft drinks, juices and water	48.23	0.3814
Coffee and tea	56.96	0.4214
Alcoholic drinks	82.12	0.5122
Other unhealthy goods	160.23	0.6720

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020).
Notes: (1) The F statistic is associated with the null hypothesis of no spatial variation in unit values; (2) p value is 0.000 for all categories.

In the first stage, we run the budget share and unit value regressions (equations (4) and (5)) and the estimated coefficients on the logarithms of total expenditure are reported in Table 8.4. Starting with

[48] As shown in Table 8.2, these categories are: (1) "Bread, cereals and flour", (2) "Milk products and eggs", (3) "Vegetables", (4) "Fruits", (5) "Potatoes, pasta and rice", and (6) "Meat".

the unit value regressions, coefficient β_g^1 is positive and statistically significant for all categories, indicating the quality upgrade for households with higher expenditure. “Milk products and eggs” category has the highest quality elasticity (0.096). Thus, the response of unit value to total expenditure is generally small for all categories. The last column, in Table 8.4, is the expenditure elasticity of quantity. As expected, all categories, but “alcoholic drinks”, are necessity goods. “Sweets”, “fish and seafood” and “other unhealthy goods” are the three categories which are closer to luxury goods. Expenditure elasticities are all statistically significant, as they are more than twice their bootstrapped standard errors. Continuing with the budged share regressions, for almost all categories, there is a negative and statistically significant relationship between household total expenditure and budged share. Only the coefficient β_g^0 for “alcoholic drinks” is positive, leading to an expenditure elasticity higher than one. The estimated coefficients for the rest independent variables are shown in Tables A.5.3 and A.5.4, in Appendix A.5, as they have little or no effect on unit values and budget shares.

Table 8.4: First stage estimates: quality and quantity effects.

Category	$\boldsymbol{\beta_g^0}$	$\boldsymbol{\beta_g^1}$	$\boldsymbol{\varepsilon_x}$	
Bread, cereals and flour	-0.016	0.037	0.459	(0.004)
Potatoes, pasta and rice	-0.007	0.078	0.319	(0.007)
Meat	-0.017	0.031	0.601	(0.003)
Fish and seafood	-0.002	0.036	0.805	(0.004)
Milk products and eggs	-0.019	0.096	0.428	(0.003)
Vegetable oils and fats	-0.007	0.019	0.522	(0.010)
Fruits	-0.007	0.072	0.492	(0.005)
Vegetables	-0.014	0.035	0.481	(0.003)
Sweets	-0.001	0.016	0.882	(0.006)
Soft drinks, juices and water	-0.002	0.040	0.640	(0.007)
Coffee and tea	-0.003	0.023	0.550	(0.006)
Alcoholic drinks	0.004	0.031	1.364	(0.004)
Other unhealthy goods	-0.002	0.021	0.803	(0.004)

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020).
Notes: β_g^0 and β_g^1 are all statistically significant at the 1% level ($p < 0.01$) except for “sweets” for which β_g^0 is statistically significant at the 10% level ($p < 0.1$); the figures in brackets are standard errors for ε_x obtained from 1,000 bootstrap replications.

Table 8.5: Estimates of own and cross price elasticities

	Bread, cereals & flour	*Potatoes, pasta & rice*	*Meat*	*Fish & seafood*	*Milk products & eggs*	*Veg. oils & fats*	*Fruits*	*Vegetables*	*Sweets*	*Soft drinks juices & water*	*Coffee & tea*	*Alcoholic drinks*	*Other unhealthy goods*
Bread, cereals & flour	**-0.962**	0.221	-0.100	0.131	0.046	-0.093	0.034	-0.086	-0.044	0.044	0.085	-0.039	<u>-0.004</u>
Potatoes, pasta & rice	0.627	**-0.913**	0.298	0.246	-0.277	-0.057	0.072	0.449	-0.385	-0.062	-0.103	0.130	-0.269
Meat	-0.073	0.070	**-0.384**	-0.073	0.146	-0.029	-0.222	<u>0.019</u>	0.049	<u>-0.007</u>	-0.062	<u>0.028</u>	-0.186
Fish & seafood	0.276	0.185	-0.241	**-0.600**	0.097	-0.257	0.165	0.184	-0.183	<u>0.004</u>	-0.273	-0.097	-0.013
Milk products & eggs	0.037	-0.082	0.178	0.041	**-1.006**	0.149	-0.015	-0.165	0.102	-0.037	-0.029	0.059	0.217
Vegetable oils & fats	-0.211	-0.047	-0.089	-0.259	0.408	**-0.363**	0.176	-0.353	0.156	-0.044	0.065	-0.086	0.166
Fruits	0.067	0.050	-0.653	0.158	-0.040	0.160	**-1.047**	-0.748	0.074	0.140	0.059	-0.067	0.201
Vegetables	-0.100	0.182	0.038	0.102	-0.232	-0.182	-0.422	**-1.287**	0.168	0.132	-0.060	0.077	<u>-0.008</u>
Sweets	-0.135	-0.384	0.185	-0.233	0.329	0.187	0.095	0.392	**-0.634**	0.094	0.081	0.069	0.183
Soft drinks, juices & water	0.218	-0.114	-0.054	0.012	-0.235	-0.101	0.345	0.572	0.175	**-1.673**	0.164	<u>0.002</u>	-0.520
Coffee & tea	0.421	-0.183	-0.443	-0.616	-0.177	0.144	0.144	-0.261	0.149	0.162	**-1.082**	0.178	0.440
Alcoholic drinks	-0.159	0.141	0.098	-0.156	0.204	-0.140	-0.122	0.197	0.076	-0.003	0.113	**-1.028**	<u>-0.006</u>
Other unhealthy goods	-0.021	-0.230	-0.646	-0.013	0.613	0.171	0.229	-0.025	0.157	-0.244	0.208	<u>0.001</u>	**-1.060**

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020). Notes: Goods in columns are those whose price is changing; Underlined figures are less than twice their standard errors; Standard errors are obtained from 1,000 bootstrap replications and presented elsewhere (see Table A.5.5, in Appendix A.5).

Table 8.5 presents the estimated own and cross-price elasticities for the thirteen good categories. All own-price elasticities are negative and statistically significant, as required by the law of demand. For half of them, demand is price inelastic. The lowest own-price elasticity is for oil and meat demand (-0.363 and -0.384 respectively), followed by fish (-0.600) and sweet (-0.634) demand. “Bread, cereals & flour” and “potatoes, pasta & rice” have also inelastic demand but their own-price elasticity (in absolute terms) is higher than 0.9. The demand for the rest categories is elastic. “Milk products & eggs”, “fruits”, “coffee & tea”, “alcoholic drinks” and “other unhealthy goods” have own-price elasticity close to one. The highest own-price elasticity is observed for “soft drinks, juices & water” (-1.673) and is followed by “vegetables” (-1.287).

As regards cross-price elasticities, the great majority are statistically significant and relatively small as about two thirds are less than 0.2 (in absolute terms). “Alcoholic drinks”, “soft drinks, juices & water” and “coffee & tea” are the categories with the lowest impact on demand for the rest of the products, followed by “sweets” and “Vegetable oils & fats” (see the corresponding columns in Table 8.5). On the other hand, the categories which are affected the least by changes in prices of other products are “Bread, cereals & flour”, “meat”, “milk products & eggs” and “alcoholic drinks”, as for each category only one cross-price elasticity is higher (in absolute terms) than 0.2 (see the corresponding rows in Table 8.5).

Focusing now on the categories which are candidates for taxation on health grounds, “sweets” is complementary to “bread, cereals & flour”, “potatoes, pasta & rice” and “fish & seafood”. This category affects mostly the demand for “potatoes, pasta & rice” with a cross-price elasticity of -0.385. The remaining cross-price elasticities are positive, indicating a substitution relationship. As regards “soft drinks, juices & water”, it is substitute with “coffee & tea”, “fruits” and “vegetables”. “Sweets” and “bread, cereals & flour” are also substitutes for “soft drinks, juices & water” but with lower cross price elasticities (less than 0.1). The greater effect of a price change in “soft drinks, juices & water” is for “other unhealthy goods” category (-0.244) while the vice versa relationship is even higher (-0.520).

“Fruits” and “vegetables”, which are the candidate categories for subsidisation on health grounds, have stronger cross-price elasticities than the categories proposed for taxation. The highest cross-price elasticity (in absolute terms) is observed between these two categories, as the cross- price elasticity between “fruits” and “vegetables” is -0.748 (and -0.422 for the opposite relationship). “Soft drinks, juices & water” is a vital substitute for both categories. A change in the price of “vegetables” (“fruits”) by 1%, will change the demand for “soft drinks, juices & water” by 0.572% (0.345%).

Other remarkable substitutes for "vegetables" are "potatoes, pasta & rice" (0.449)[49] and "sweets" (0.392). Except of "fruits", the other complementary goods to "vegetables" are "vegetable oils & fats" (-0.353), "coffee & tea" (-0.261) and "milk products & eggs" (-0.165) and, to a lesser degree, "bread, cereals & flour" and "other unhealthy goods". As regards "fruits", the majority of cross-price elasticities (two thirds) are positive. Apart from "vegetables" and "soft drinks, juices & water" for which the effects have already been mentioned, a change in the price of "fruits" will have a stronger effect on consumption of "meat"[50] and "other unhealthy goods" (cross- price elasticities are -0.222 and 0.229, respectively). The remaining cross-price elasticities for "fruits" (in absolute terms) are less than 0.2.

For the remaining categories, it is worth noticing that "bread, cereals & flour" is a great substitute for "potatoes, pasta & rice" (0.627). Also, the category "other unhealthy goods" is highly affected by changes in price of "meat" (-0.646) and "milk products & eggs" (0.613). On the other hand, "coffee & tea" seems to be a problematic category as its demand alters vitally with the price of "bread, cereals & flour", "meat", "fish & seafood" and "other unhealthy goods" (the cross-price elasticities are 0.421, -0.443, -0.616 and 0.440, respectively).

Table 8.6: Estimates of own- price elasticities by groups – 5 quantiles excluding zero-consumption

	Soft drinks, juices & water	*Sweets*	*Fruits*	*Vegetables*
	Groups by pc total expenditure			
Low	-1.919	-1.493	-1.143	-2.067
High	-1.194	-0.703	-1.196	-1.324
Difference	0.725	0.791	0.054	0.743
	Groups by pc expenditure on each category			
Low	-1.553	-1.779	-1.384	-1.206
High	-1.306	-0.731	-1.068	-0.995
Difference	0.247	1.047	0.316	0.212

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020).
Note: Difference is in absolute terms.

[49] It is the cross- price elasticity for "potatoes, pasta & rice" with respect to the price of "vegetables".
[50] The vice versa effect is even higher as a price increase of "meat" by 1% will decrease demand for "fruits" by 0.653%.

It is also interesting to examine whether own-price elasticities, for the four categories of interest here, vary among households based on purchases on each category as well as total expenditure. Specifically, own-price elasticities are estimated at five different quantiles based on per capita total expenditure.[51] The top half of Table 8.6 presents the results for the first (low) and fifth (high) quantile. For fruit, there is negligible variation between the two groups. Regarding the other three categories, households with lower per capita total expenditure are more sensitive to price changes as their own-price elasticity (in absolute terms) is higher by about 0.7.

Own-price elasticities for each category are also estimated based on per capita expenditure on this category. As with "income" groups, households are divided into five groups (quantiles), after excluding those reporting zero expenditure for the category examined each time.[52] The results for light- and heavy-consuming households are shown in the bottom half of Table 8.6. In each category, heavy-consuming households respond less to price changes. The greater variation between upper and lower quartile is observed in own-price elasticity of "sweets" (-1.779 for low consumers versus -0.731 for high consumers).

8.6 Fiscal Policy Effects

Having estimated the own and cross-price elasticities, it is now possible to examine the effects of different tax and subsidy scenarios (see Table 8.7). Starting with the tax policies, a 20% tax on soft drinks and juices is expected to reduce the demand for this category by 33.46%, while a 20% tax on "sweets" has a lower impact as demand for sugary products will be reduced by 12.69%. Combining the two tax policies, the total effect on demand for these two categories is lower, as these goods are substitutes, but demand falls only by a small percentage. Specifically, the tax effect on demand for "soft drinks, juices & water" will be - 29.97% while for "sweets" becomes - 10.80%.

Continuing with the third scenario, a 19.35% subsidy on "fruits"[53] results in a 20.27% increase in their demand. A corresponding subsidy on "vegetables" will have a greater impact, rising the demand for this category by 24.90%. "Fruits" and "vegetables" are strong complementary goods and the combined

[51] Total expenditure is used instead of income to determine the income status as, for 41.86% of households, expenditure exceed income.

[52] For example, if the category is "sweets", we exclude households with zero expenditure on "sweets" and the remaining households are divided into five quantiles based on their per capita expenditure on "sweets". Households with zero expenditure are excluded as we are interested to examine the difference between light and heavy consumers.

[53] This is equivalent to a zero VAT.

subsidy policy yields an increase in fruit and vegetable consumption by 34.75% and 33.08%, respectively.

Table 8.7: Tax and subsidy effects on demand

Category	*20% tax on soft drinks*	*20% tax on sweets*	*Total tax effect*	*19.35% subsidy on fruits*	*19.35% subsidy on vegetables*	*Total subsidy effect*	*Total tax & subsidy effect*
Categories affected directly by fiscal policies							
Soft drinks, juices & water	-33.46	3.49	-29.97	-6.68	-11.08	-17.76	-47.73
Sweets	1.89	-12.69	-10.80	-1.83	-7.59	-9.42	-20.22
Fruits	2.81	1.47	4.28	20.27	14.48	34.75	39.03
Vegetables	2.64	3.36	6.00	8.18	24.90	33.08	39.08
Categories affected indirectly by fiscal policies							
Bread, cereals & flour	0.89	-0.88	0.00	-0.65	1.66	1.01	1.01
Potatoes, pasta & rice	-1.24	-7.70	-8.94	-1.39	-8.69	-10.08	-19.02
Meat	-0.14	0.98	0.84	4.30	-0.38	3.92	4.76
Fish & seafood	0.09	-3.66	-3.58	-3.18	-3.55	-6.74	-10.31
Milk products & eggs	-0.74	2.03	1.29	0.30	3.20	3.50	4.79
Vegetable oils & fats	-0.88	3.11	2.23	-3.41	6.84	3.43	5.66
Coffee & tea	3.24	2.97	6.21	-2.80	5.06	2.26	8.47
Alcoholic drinks	-0.07	1.52	1.45	2.36	-3.80	-1.45	0.01
Other unhealthy goods	-4.88	3.14	-1.74	-4.42	0.48	-3.95	-5.69

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020).

A mixed tax – subsidy policy on the aforementioned categories (third scenario) will result to a greater impact on their demand, since the subsidy policy enhances the effect of the tax policy, and vice versa. The boost will be higher for unhealthy categories with the demand for “soft drinks, juices & water” and “sweets” being further reduced by 17.76% and 9.42%, respectively. Thus, the total (tax and subsidy) effect will be -47.73% and 20.22%, respectively. On the other hand, demand for fruit and vegetables increases more because of the tax policy but to a lesser degree. Specifically, demand for fruit increases by 4.28% and for vegetables by 6.00%, yielding a total (tax and subsidy) effect of about 39% for each.

The taxes and subsidies will also affect the demand for the rest of the goods because of the cross-price effects. Among the different tax and subsidy policies, the tax on soft drinks and juices has the lowest impact on demand for the other goods, with the highest impact on “other unhealthy goods” (-4.88%). On the other hand, the greater effect on demand for the rest of the goods is observed after implementing the subsidy on “vegetables”. In that case, categories affected the most are “potatoes, pasta & rice” (-8.69%) and “vegetable oils & fats” (6.84%). The combined tax and subsidy policy has as a result a decline in demand for “potatoes, pasta & rice” and “fish & seafood” by 19.02% and 10.31%, respectively. These two categories face the greater impact and along with “other unhealthy goods” are the only categories affected negatively. For the rest of the categories, demand is expected to increase but by a relatively small percentage (less than 10%) (see Table 8.7).

8.7 Discussion and Conclusions

In the first part of this chapter, own and cross- price elasticities for thirteen good categories were estimated using data from the 2019 Greek HBS (ELSTAT, 2020). Results show that about half of good categories have inelastic demand and only “alcoholic drinks” is a luxury good. As regards cross-price elasticities, about two thirds are relatively small (less than 0.2 in absolute terms). Category “coffee & tea” seems to be a problematic one as its demand is highly affected by changes in price of “bread, cereals & flour”, “meat”, “fish & seafood” and “other unhealthy goods”. The characteristic of this category is that it has high unit value and relatively high proportion of households with zero expenditure. The combination of these two factors might have led to these elasticities.

The study then focuses on the categories which are candidates for fiscal policy implementation. These are “soft drinks, juices & water”, “sweets”, “fruits” and “vegetables”. For these categories, price elasticities were estimated by income groups. Per capita total expenditure was used as a proxy for income and results for the upper and lower quantile were presented. As expected, low-income households are more sensitive to price changes. Thus, a fiscal policy will affect more low-income households increasing (decreasing) relatively more the demand of subsidised (taxed) products. Given that demand of these categories is elastic for low-income households, expenditure is expected to decrease for taxed products and increase for subsidised ones.

Findings on price elasticities by type of consumer are also interesting. The set of price elasticities was estimated four times. Each time households were separated into five quantiles based on their per capita expenditure on category of interest (“soft drinks, juices & water”, “sweets”, “fruits” and “vegetables”). It seems that for all four categories, households with heavy-consumers are less sensitive to price changes, since they are more willing to pay more compared to light-consumers. Another explanation is that households in the upper quantile are in a better financial situation as the mean per capita total expenditure is higher than the corresponding for households in the lower quantile. Comparing now the elasticities by type of consumer with those for the average household, it is indicated that mean own-price elasticities for “sweets” and “fruits” are closer to those for heavy-consumers while the opposite occurs for “soft drinks, juices & water” and “vegetables”.

In the second part of this study, we investigated the effects of different tax and subsidy scenarios. Following the WHO recommendations, the first scenario is a 20% tax on SSBs, including juices but also unsweetened beverages and carbonated water.[54] Demand for “soft drinks, juices and water” is expected to be reduced by about one third but the effect on other food categories will be limited. Thus, a tax only on this category might not have the desired effect. Adding a 20% tax on sweets, it will have a greater impact on sugary goods’ consumption, without increasing significantly the demand for other unhealthy foods.

For a more publicly acceptable policy, we also examined a zero-rate subsidy[55] (from the current 24% VAT) on fruits and vegetables. Results show a satisfactory increase in demand for both fruits and vegetables (about one third), which is also accompanied by a significant reduction in taxed goods. Thus, the combined policy of taxes and subsidies yields better results for healthy consumption, as one policy enhances the other. Also, the combined policy reduces the demand for other unhealthy products which is a step to the right direction. However, there is a significant negative impact on fish (-10.31%) and “bread, cereals and flour” (-19.02%) demand. Based on data presented in Section 1.1.1, cereals supply is high in Greece and there might be room to reduce it but the same does not occur for fish. Last but not least, the combined scenario increases demand for fatty products (meat, milk and vegetables oils) but by a small proportion.

In evaluating these results, we should take into account that, for some products, quantity reported is not purchased but obtained through other forms, such as own production. Based on the 2019 HBS

[54] Finland is an example of a country implementing a tax also on unsweetened beverages and carbonated water.
[55] A zero VAT tax has been asked to be considered by the European Council when revising the EU VAT framework (Foodwatch, 2021)

study (ELSTAT, 2020), products with great own production are vegetables oils (mainly olive oil), vegetables, fruits, meat and “potatoes, pasta and rice”. For these products, the own production as percentage of total purchases for that category is 25.15%, 16.23%, 11.56%, 11.49% and 10.46%, respectively (see, Graph A.5.6, in Appedix A.5). This condition is something that is of concern to us, mainly in the case of a tax on fat.

This study uses the “unit value” model by Deaton (1988). An alternative method is the AIDS model (Deaton and Muellbauer, 1980) which has been very popular. The “unit value” model was chosen for two reasons. First of all, in the AIDS model, budget shares are strictly positive while “unit value” model allows also for zero expenditure. Including all households is vital when fiscal policy impacts are examined as households with zero purchases might start consuming if prices decrease, income increases, etc. (John et al., 2019). Another reason is that in “unit value” model, consumers choose both quantity and quality. However, results show that quality elasticity is small for all categories and including quality effects does not change results significantly.

This study has some limitations. A key assumption of the model used is that prices are the same within clusters. The validity of this assumption requires that households are located in the same geographical area and interviewed at the same time. At the 2019 HBS, households are divided into strata based on their geographical location and the degree of urbanization, and interviewed at the same period. However, the number of strata is only 72 which means that geographical areas are not as small as required. Instead of strata, it would be better to use the primary sampling units which are 1,016 but this information, while it exists, is not available for public use. Secondly, HBS does not distinguish between zero expenditures and expenditure information that is simply missing. If we want to draw the right conclusions about household habits, it is important to know if the selected household does not prefer a particular good or it just happened not to buy it at the time of interview. Thirdly, a relevant and supplementary problem is that the total duration of the HBS is fourteen continuous days which is considered short. There are goods sold in great quantities (e.g., olive oil) or with long expiration date (e.g., canned food) that households might consume them often but buy them rarely. For such goods, the survey does not capture their real consumption.

Another limitation is the categorization of goods. Some categories would be better to split into two sub-categories, one healthy and one unhealthy based on their fat content (e.g., milk products and meat), the sugar content (e.g., soft drinks) or the fiber content (e.g., bread and pasta). These data exist but are not publicly available. For policy implementation, further categories would be preferable but this creates another problem. Specifically, creating more categories results in each category having fewer goods. Thus, for each category, the proportion of households with zero expenditure is more likely to increase, which is not desirable. This is the reason why, for example, eggs are in the same category with milk products and not separately.

Results of this study are crucial as they describe the current food demand in Greece and, hence, constitute important guidance for fiscal policies related to diet. However, if the appropriate data are available, a future study will be necessary so as to make a better food categorization based on their nutritional content. That will allow us to examine a tax on fat as well as a tax only on most unhealthy foods in a category (and not on the whole category), which with the current data is impossible.

Conclusions

This thesis highlights the obesity problem in Greece which is among the EU countries with the highest prevalence of overweight and obesity for both adults and children. Evidence about eating habits show that, with the passing of years, Greeks diverge from the healthy Mediterranean diet, increasing the consumption of fatty products (e.g., sugar, vegetable oils and dietary products) and decreasing the consumption of healthy goods (e.g., pulses). This increases the daily calorie supply as well as calories from fat as percentage of total calories.

Unhealthy eating and the obesity problem lead to a series of health and economic consequences. Both of them increase the risk of developing a disease, such as diabetes, and are among the risk factors with the highest death and YLD rates. The first aim of this thesis is to shed light on the economic costs of diseases related to unhealthy diet and excess body weight in Greece. This study is the first regarding the economic cost of dietary risks and the most detailed and completed for the economic cost of tobacco use (the leading risk factor). Estimates are based on the cost of illness approach, which gives results that lie between those of the two alternative methods (friction cost method and willingness to pay approach). Based on this method, the total economic cost consists on the direct cost (healthcare expenditure) and indirect cost which is the sum of morbidity and mortality cost, calculated as productivity loss.

Results show that, in 2019, the total economic cost of dietary risks and high body BMI is 2.52% and 2.00% of GDP, respectively. These amounts are translated to €422.3 and €335.1 per capita. The direct cost exceeds indirect cost for dietary risks (60.89% of total cost) but the opposite occurs for high BMI (41.35% total cost). As regards indirect cost, for both risk factors, mortality cost is higher that morbidity cost. Results by gender show that the indirect cost is lower for females because of the lower labor market participation and death rates. Also, for each risk factor, about 50% of morbidity cost and 56% of mortality cost is due to people aged 45-59 years. This results from the combination of high employment-to-population rates and relatively high numbers of YLDs and deaths. The main cause of morbidity is diabetes accounting for 50.2% (high BMI) and 68.04% (dietary risks) of morbidity cost. On the other hand, cardiovascular diseases are responsible for the greater amount of mortality cost (83.72% for high BMI and 91.46% for dietary risks). This is expected as, for these risk factors, there is a relatively small number of diseases which lead to death (four for dietary risks and seven for high BMI) and cardiovascular diseases are generally the most common cause of death.

In the main analysis of the economic cost of risk factors, the mortality cost is estimated assuming non-discounting (r=0%). This rate is chosen based on the recent belief that human life should not be discounted. However, for a sensitivity analysis, mortality cost is also estimated assuming a discount rate of 3%, which is common in cost studies. Generally, the higher the discount rate, the lower the discount rate is. In this case, the mortality cost is lower by about 19.1% and the total cost decreases by 3.67% (high BMI) and 4.48% (dietary risks). Additionally, for a ten- and twenty-year comparison, the economic cost is also estimated for years 1997 and 2007. For both risk factors, the total economic cost increases greatly in the first decade (1997-2007) but decreases in the second one (2007-2017). The reduction in the second period is highly affected by the socioeconomic situation of Greece as, due to economic crisis, employment rates and GDP per worker shrank. The reduction in mortality cost is also boosted by decreases in number of deaths. On the other hand, the direct cost decreases due to a reduction in both PAFs and healthcare expenditures. For the twenty-year period, the net results is a raise in total cost by 2.31% for dietary risks and 14.16% for high BMI.

The contribution of the cost study is vital as it underlines the heavy economic burden that unhealthy eating and obesity impose to society and provides useful information to government. Combining these results with the evidence about the increasing trend on overweight and obesity as well as the changes on dietary habits, the need for immediate action is emphasized. Among the different policies to prevent and combat obesity, the focus of this thesis is on fiscal policies, i.e., sin taxes and thin subsides. A special interest is given to sin taxes on unhealthy goods as, contrary to other policies, it constitutes a good source of revenue. The revenue could be used to finance complementary policies such as subsidies on healthy goods, free meals at school and information campaigns.

To contribute in this field, the optimal sin tax is examined using a theoretical model. It is assumed that individuals differ in their income and the degree of misperception regarding the health consequences of unhealthy consumption and the benefits from healthy consumption. Also, because misperception is linked with income, it is shown that low income individuals consume more (less) of the unhealthy (healthy) good than high income individuals.

Two scenarios are examined based on the way the tax revenue is used. It the first case, raised revenue from tax is returned to individuals via a lump-sum transfer while in the second case the tax revenue is used to finance a subsidy on healthy good. Each scenario is examined with and without distributional concerns. Results show that, in the absence of distributional concerns, the way the government uses tax revenue (lump-sum or consumption subsidy) does not affect the optimal tax. In both cases, the purpose of the tax is to correct the individual misperceptions and it is equal to the weighted average of individual misperceptions regarding marginal harm. Similarly, when the tax revenue is used to subsidise the healthy good, the corrective subsidy is equal to the weighted average of individual marginal misperception regarding the healthy good. Assuming prudence, the tax (subsidy) is higher (lower) than the average internality misperception related to unhealthy (healthy) good consumption. Since low-income individuals consume more of the unhealthy good, both schemes are regressive. The second scenario is even more regressive because low-income individuals consume less of the healthy good and, as a result, they benefit less from the subsidy.

When distributional concerns exist, the tax has a corrective term, as before, but also a redistribution term. In this case, the tax is lower compared to the case with no distributional concerns and it is less regressive. However, low-income individuals are those who will benefit more on health terms and thus the tax is health progressive. In the case where the tax revenue finances a subsidy on healthy good, the subsidy rate will be higher compared to the case with no distributional concerns. As mentioned before, with no redistribution concerns, the tax (subsidy) is higher (lower) than the average internality misperception. Including distributional concerns, the tax rate decreases and the subsidy rate increases, going closer to the average corresponding internality.

When progressivity matters for the government, the most appropriate scheme is one of those with distributional concerns as the tax rate is lower compared to the corresponding purely corrective schemes. However, it is difficult to choose one of them as the tax rates are not comparable. If we focus on the way the tax revenue is used, the less regressive scheme seems to be the one that returns the revenue as a lump-sum transfer. This occurs because, with the appropriate redistribution, low-income individuals could benefit more than high-income individuals. On the other hand, if government choose the subsidy, low-income individuals benefit less than high-income ones as they consume less of the healthy good.

If the purpose is to improve health status, then government should focus on schemes with no distributional concerns as the tax is higher. Generally, results show that there is a positive relationship between income regressivity and health progressivity. Thus, to achieve the highest possible health improvement, government should implement the most regressive scheme, i.e., the tax – subsidy scheme. In this case, individuals benefit not only from the decrease in unhealthy good consumption but also from the increase in healthy good consumption. An intermediate solution could be the tax-subsidy scheme with distributional concerns. It is less regressive (lower tax and higher subsidy) and, in health terms, even if individuals loose from the lower decrease on healthy good consumption, they gain from the higher increase in healthy good consumption.

Having drawn the above-mentioned conclusions regarding the optimal fiscal policy, then we examine the implementation of different fiscal policies for public health in Greece. To achieve that, at a first stage, the demand for thirteen food and beverage categories is determined, estimating own- and cross-price elasticities. The model used is the "unit value" model by Deaton (1988) and it is chosen for two reasons. First of all, it is among the models which need data on household expenditure and this is the only way we can estimate price elasticities based on data availability in Greece. Secondly, it takes into account households with zero consumption which is desirable when the purpose is to examine public policies. Based on data from the 2019 Greek HBS, about half of the categories have inelastic demand and all goods are normal with "alcoholic drinks" being a luxury good. As regards cross-price elasticities, about two thirds are less that 0.2 (in absolute terms).

The focus then turns on candidate categories for fiscal policy intervention, which are "soft drinks, juices & water", "sweets", "fruits" and "vegetables". For these categories, estimated own-price elasticities are -1.673, -0.634, -1.047 and -1.287, respectively. Results by income group and type of consumer show that low-income households are more sensitive to price changes, especially for "sweets" and "vegetables". The opposite occurs for households with heavy consumers as they are less sensitive to price changes. Thus, a tax on the unhealthy goods is expected to affect less the targeted households (heavy consumers) and more the low-income households. However, since demand is elastic for low-income households, the price increase will lead to a decrease in expenditure for the taxed products.

At a second stage, different fiscal scenarios are examined based on recommendations and existing policies in other countries. According to the WHO guidance, SSBs should be taxes by at least 20%. In this study, this tax is applied not only on SSBs but the whole category of "soft drinks, juices & water", following the example of other countries such as Finland. As an alternative or supplementary policy, the same amount of tax is also introduced on "sweets". On the other hand, for a more publicly acceptable policy, we examine the implementation of a 19.35% subsidy on "fruits" and "vegetables" which is equivalent to a zero VAT tax (from the current 24%)[56].

Results show that a 20% tax on "soft drinks, juices & water" is expected to reduce its demand by about one third with limited effects on other categories demand. Taking into account that SSB consumption

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[56] Note that if P_A is the VAT exclusive price and P_B is the VAT inclusive price, it holds that $(1 + \mathrm{VAT})P_A = P_B$. With a subsidy equivalent to a zero VAT tax, the initial consumer price is P_B and the final consumer price is P_A. Thus, the percentage change on consumer price is $\Delta P\% = [(P_A - P_B)/P_B] \times 100 = \{[P_B/(1 + \mathrm{VAT}) - P_B]/P_B\} \times 100 = -[\mathrm{VAT}/(1 + \mathrm{VAT})] \times 100$. For a $\mathrm{VAT} = 24\%$, $\Delta P\% = -19.35\%$. Thus, prices should decrease by 19.35% to reach the VAT exclusive prices.

in Greece is relatively small, compared to other counties (e.g., USA), a single tax on this category might has limited effects on body weight. Adding a 20% tax on sweets, it seems as a better option as the impact on both taxed categories will be greater, without significantly affecting the demand for other unhealthy products. On the other hand, a subsidy on fruits and vegetables has shown to have great effects for all four categories of our interest. However, a subsidy policy alone will create a heavy cost for the government and might deprive funds from other equally important policies. A mixed tax-subsidy policy seems promising as one policy enhances the other one. The mixed policy is expected to have significant effects on targeted categories demand, reducing the demand for "soft drinks, juices & water" (by 47.73%) and "sweets" (by 20.22%) and increasing the demand for "fruits" (by 39.03%) and "vegetables" (by 39.08%). Results from econometric model are in line with results from theoretical model as both of them conclude that a combine tax – subsidy policy is more preferable than pure tax policy.

To put matters into perspective, we are also interested in tobacco use as it is the leading risk factor in Greece for which successful measures have already been taken. However, despite the decrease in smoking prevalence, deaths and YLD rates continue to increase and, only after 2017, a stabilization on tobacco-related YLD rates is observed. This is not surprising as there is a time lag in the onset of health problems while the health benefits of quitting smoking appear after some years. The economic cost of tobacco use (both tobacco smoking and SHS exposure) is estimated at 3.85% of GDP. As expected, this is higher than the economic cost of high BMI (2.00% of GDP) and dietary risk (2.52% of GDP). However, contrary to the other examined risk factors, in a twenty-years comparison, the economic cost of tobacco use presents a slight reduction.

To conclude, in the effort to prevent and combat obesity, there is still a lot of work to be done. Imposing sin taxes on unhealthy goods is a promising policy which contributes directly with the decrease of unhealthy consumption but also indirectly by providing funds for complementary policies. A combined tax-subsidy policy seems to be better than a single tax policy as it will be more effective and acceptable to the citizens. The tobacco example shows that prevention policies could be effective and it highlights the need for immediate interventions as the health results need time to be noticeable.

Ideally, we would like to estimate price elasticities for sub-categories, separating healthier and unhealthier product (e.g., whole-fat and low-fat milk, low fibre and whole meal bread etc.), and examine the tax effect on specific products of a category. This would allow us to examine a tax on fatty products, for which evidence shows an increasing trend on consumption. However, such a study requires analytical data which, at least up to now, were not publicly available.

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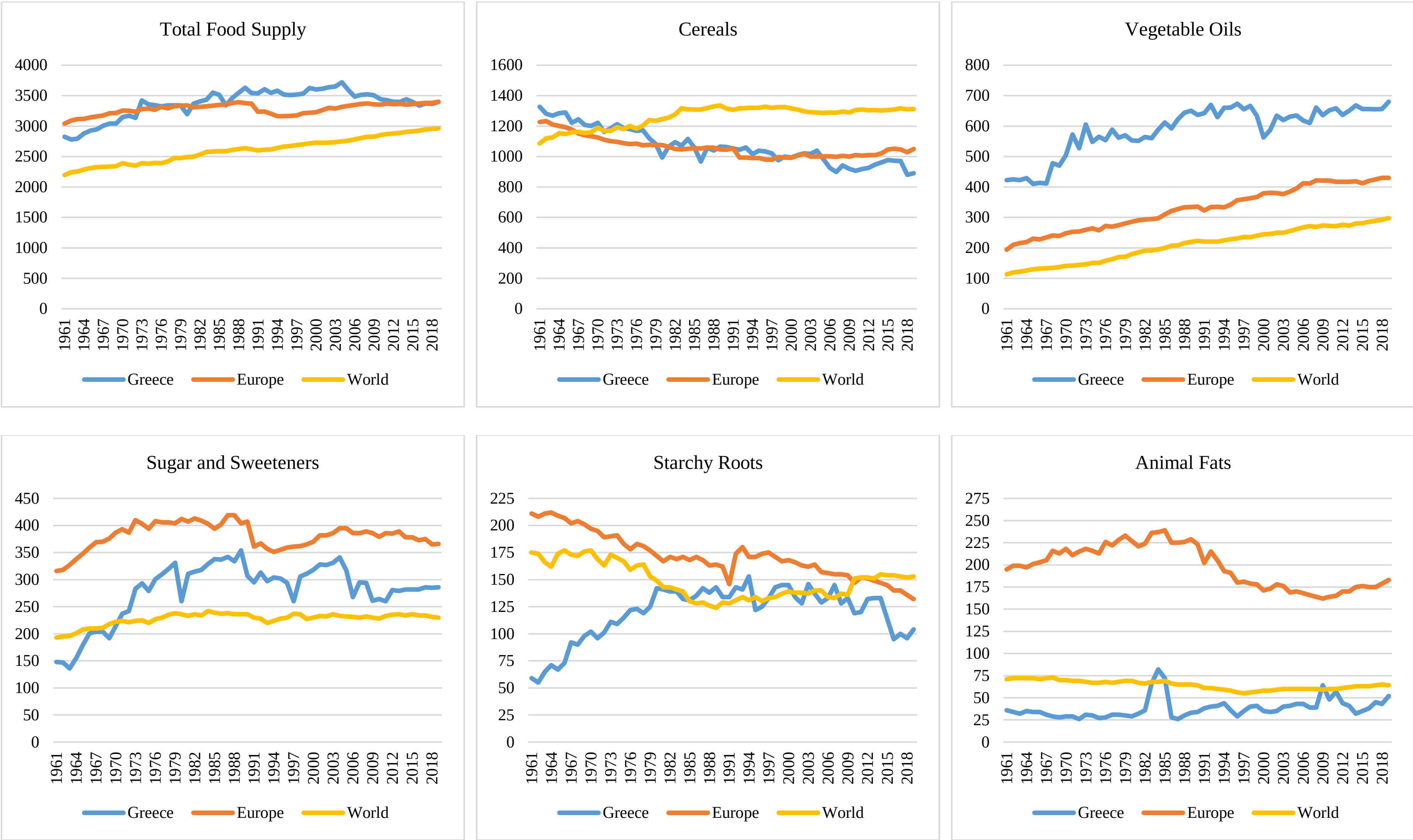
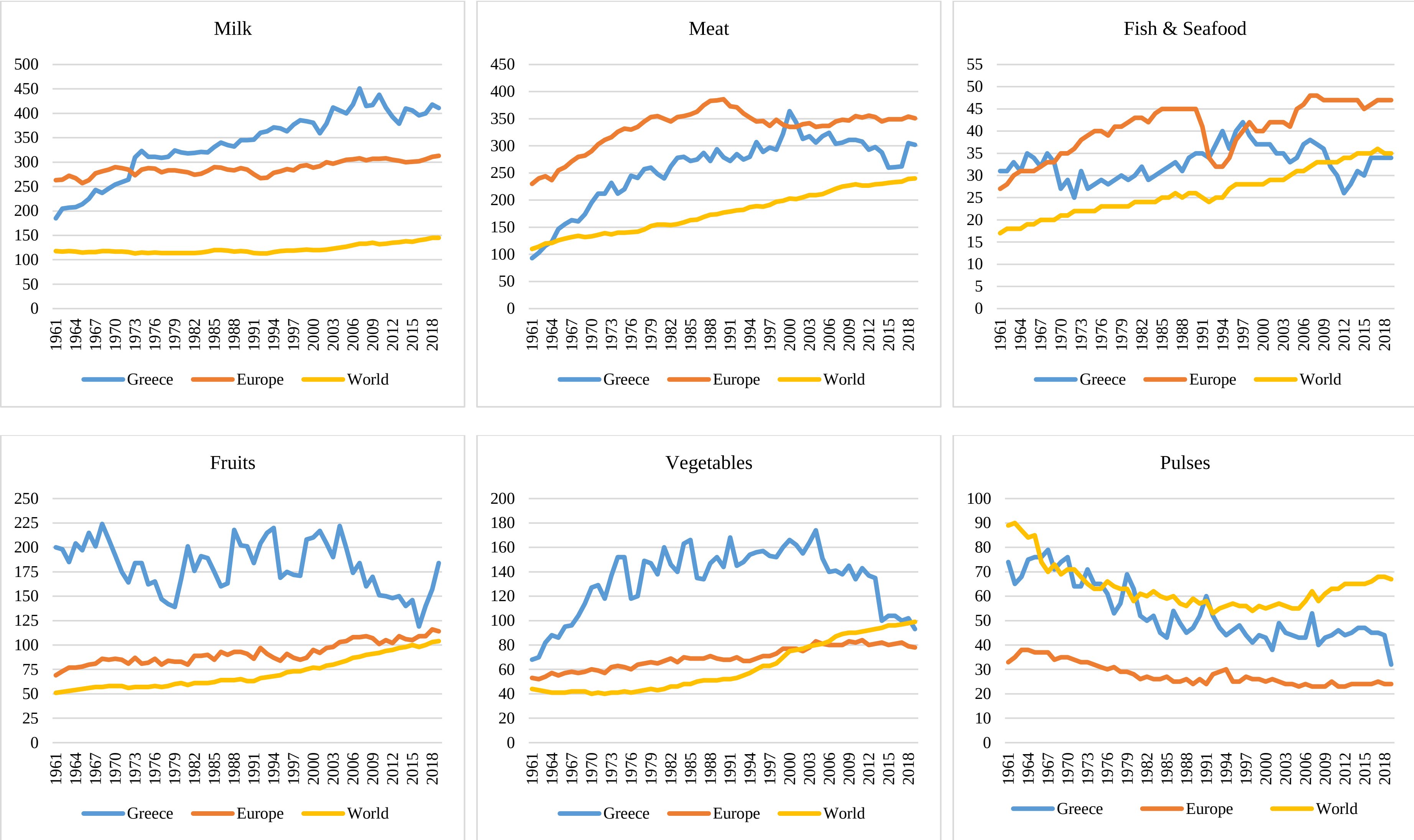
Appendices

A.1 Evidence on Dietary Patterns, Overweight/Obesity and Tobacco Use

Graph A.1.1: Food supply (kcal/capita/day), total and by food category, 1961-2019

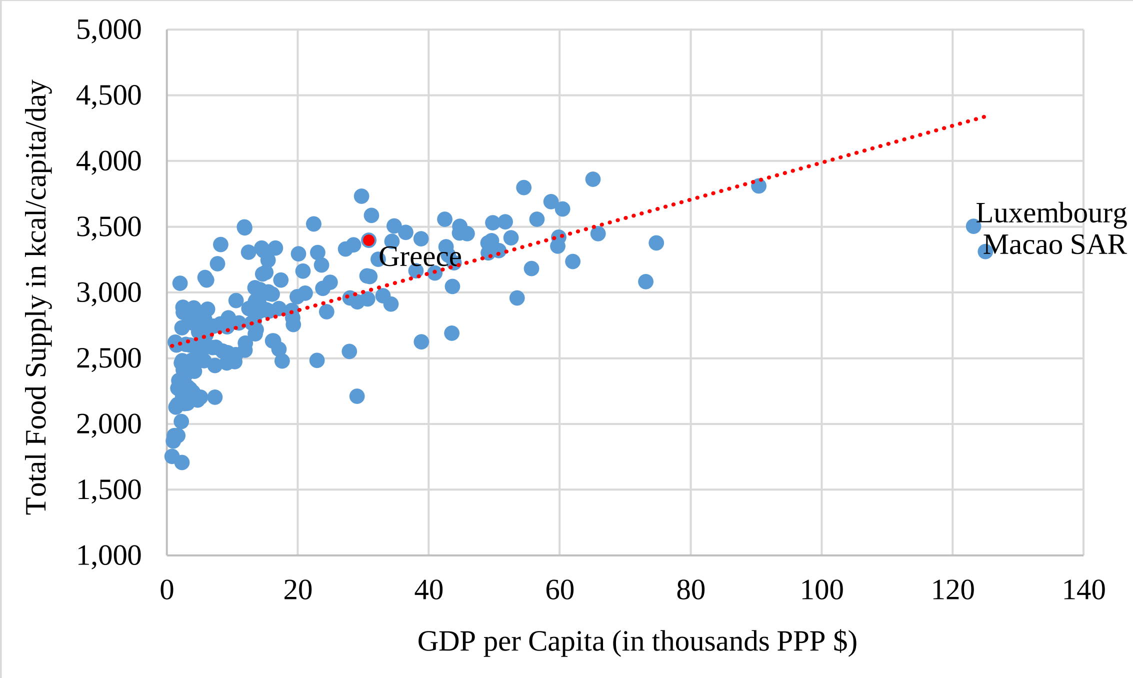


Graph A.1.1: Food supply (kcal/capita/day), total and by food category, 1961-2019 (continued)



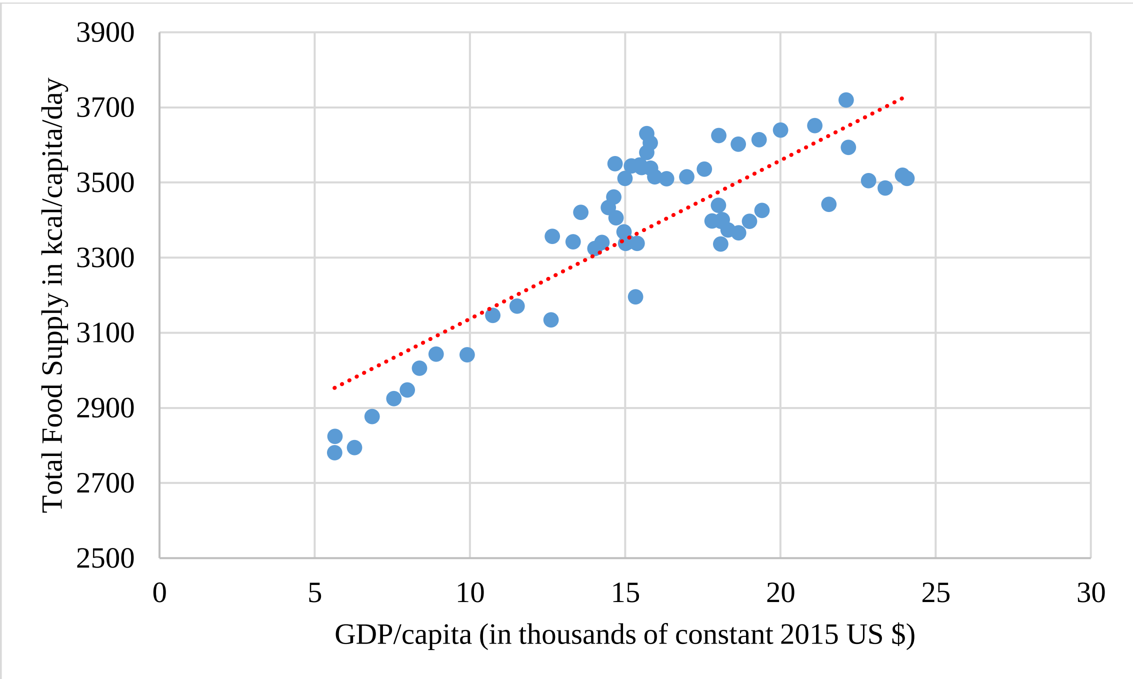
Sources: Food supply from FAO (FAO, 2022); GDP from OECD.Stat (OECD, 2022)

Graph A.1.2: Total food supply (kcal/capita/day) and GDP/capita (PPP $) for 175 countries, 2019



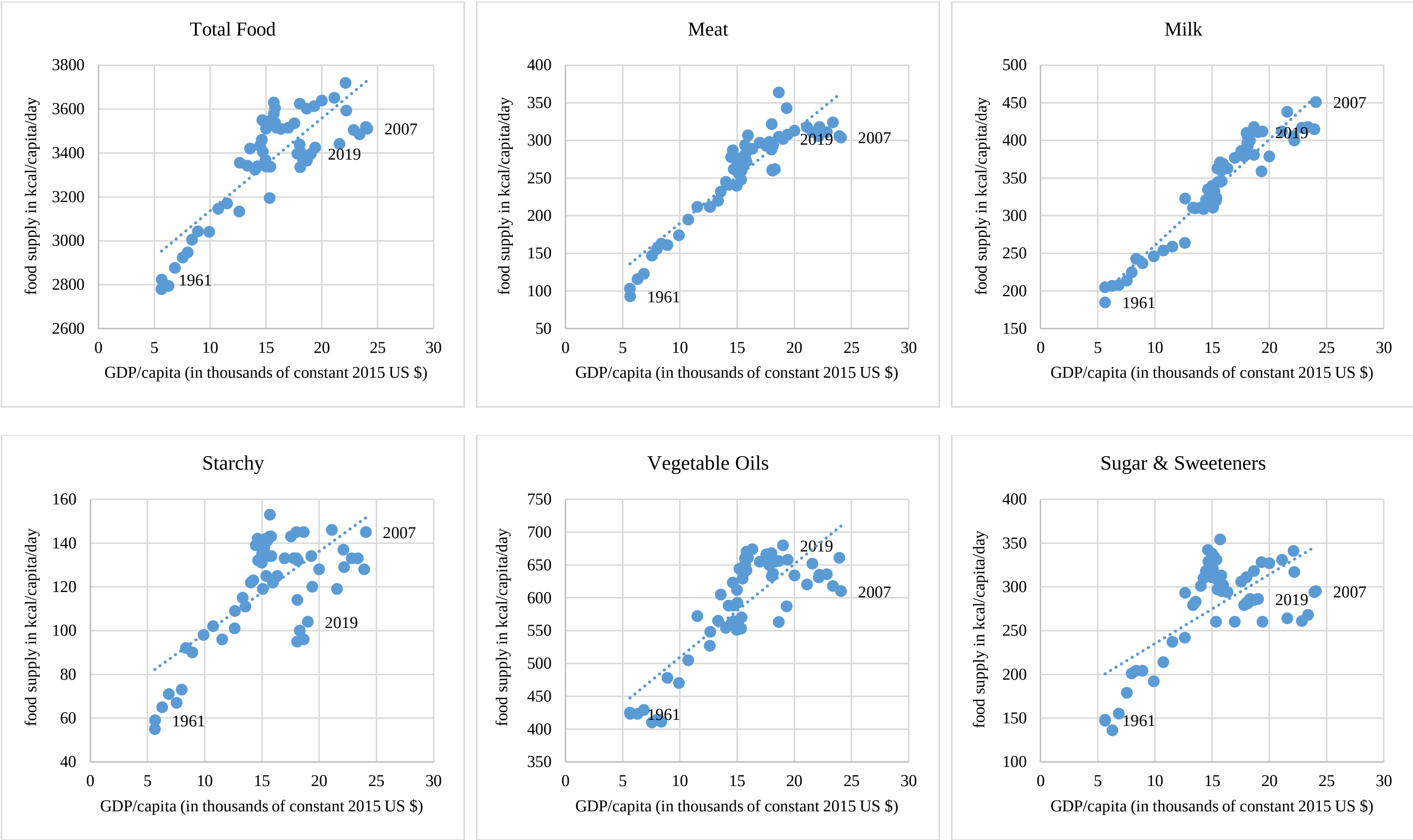
Sources: Food supply from FAO (FAO, 2022a); GDP from the April 2022 World Economic Outlook Database (IMF, 2022)

Graph A.1.3: Total food supply (kcal/capita/day) and GDP/capita (constant 2015 US $), Greece, 1061-2019

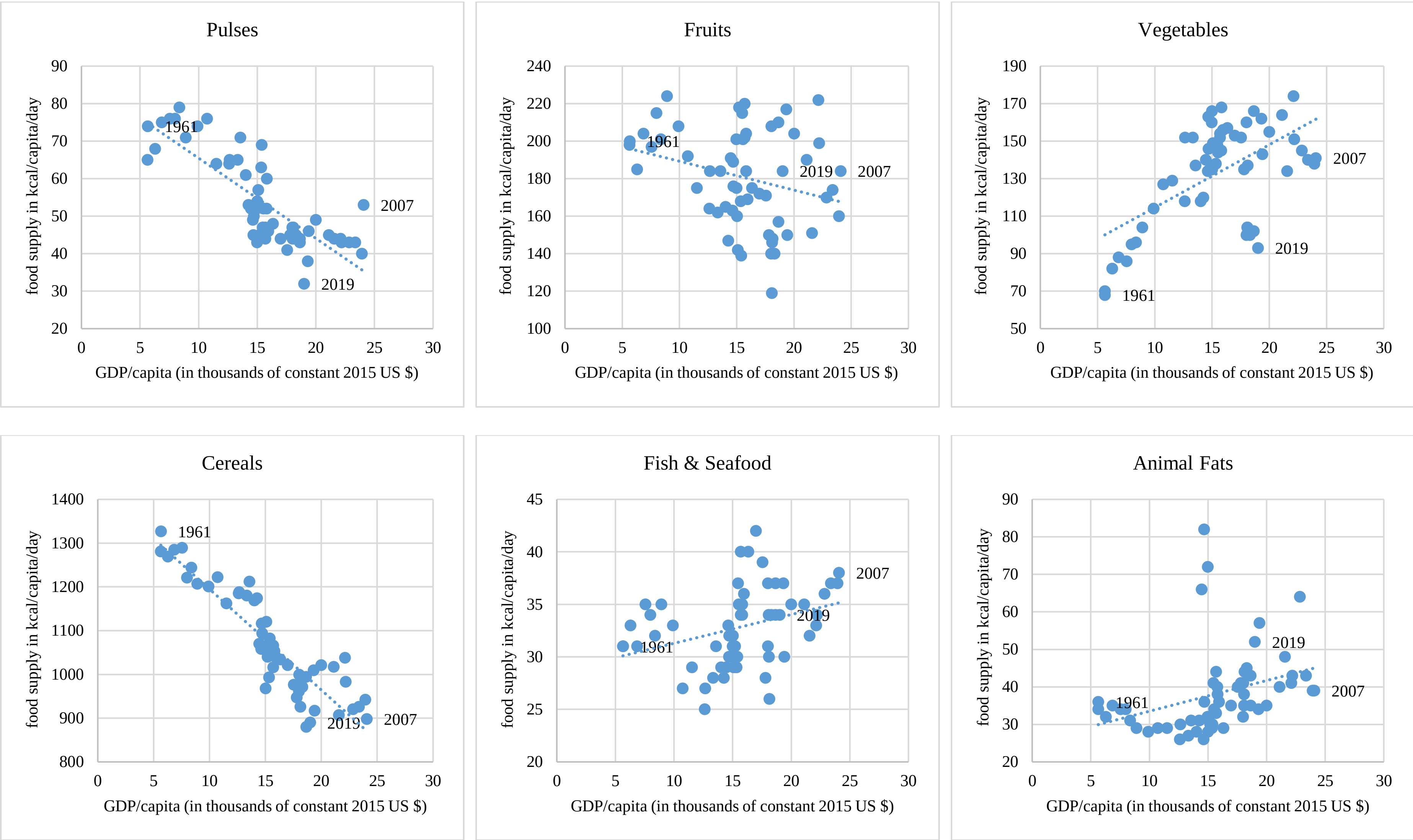


Sources: Food supply from FAO (FAO, 2022a); GDP from OECD.Stat (OECD, 2022)

Graph A.1.4: Food supply (kcal/capita/day) and GDP/capita (constant 2015 US $), by food category, Greece, 1061-2019

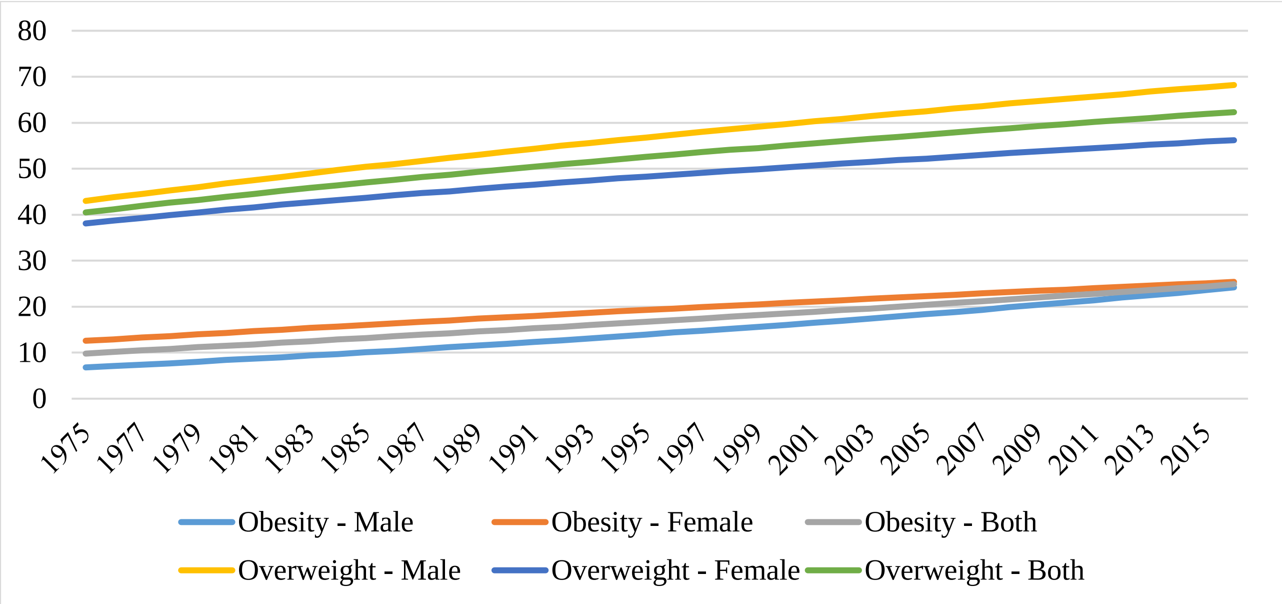


Graph A.1.4: Food supply (kcal/capita/day) and GDP/capita (constant 2015 US $), by food category, Greece, 1061-2019 (continued)



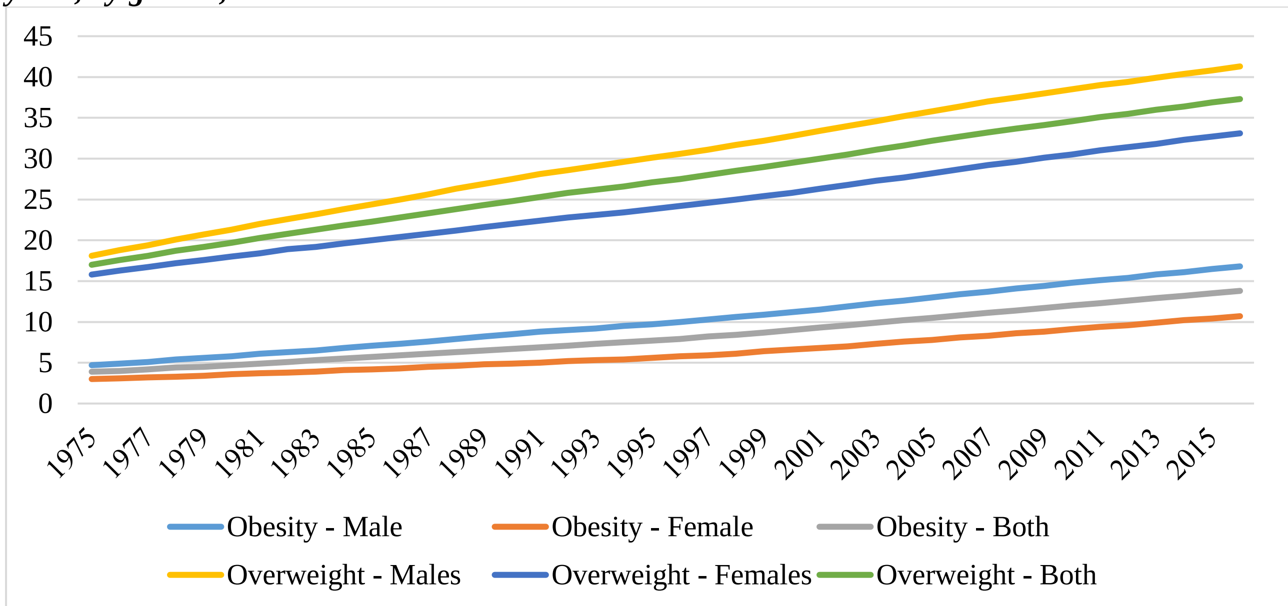
Sources: Food supply from FAO (FAO, 2022); GDP from OECD.Stat (OECD, 2022)

Graph A.1.5: Age-standardized prevalence of overweight (BMI≥25) and obesity (BMI≥30) among adults, by gender, 1975 -2016 estimates



Source: Global Health Observatory data repository (WHO, 2017a)

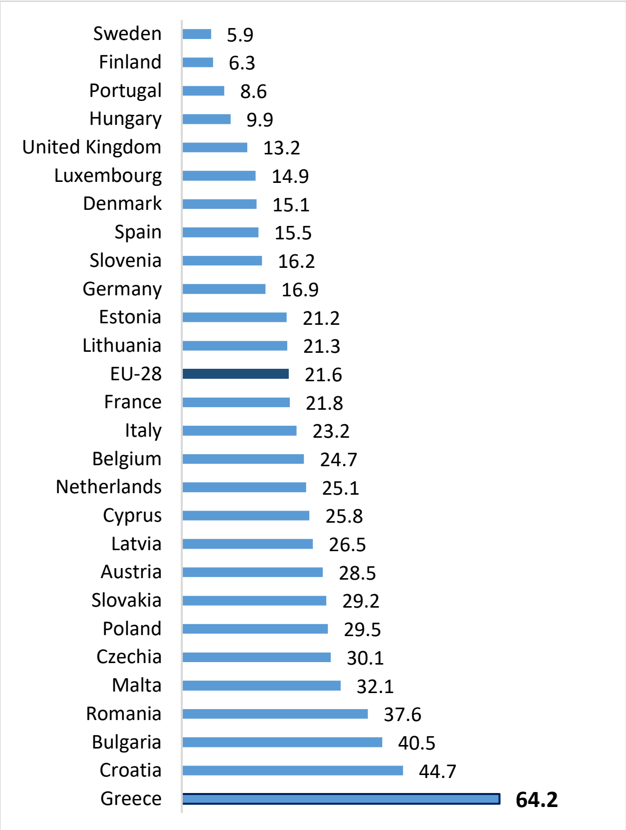
Graph A.1.6: Age-standardized prevalence of overweight and obesity among children aged 5-19 years, by gender, 1975 -2016 estimates



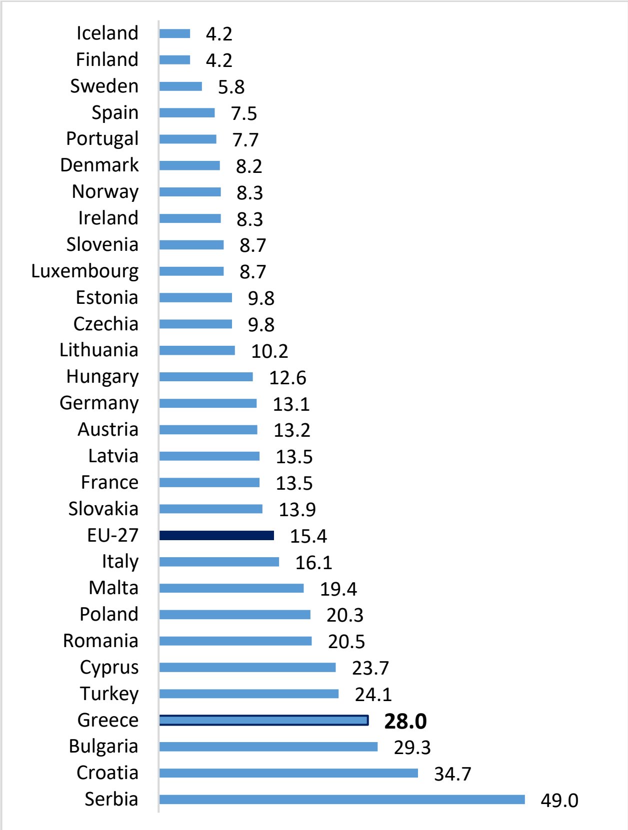
Source: Global Health Observatory data repository (WHO, 2017a)

Graph A.1.7: Daily exposure to tobacco smoke indoors, people aged ≥ 15 years, EU Member States, 2014 and 2019

<u>***2014***</u>

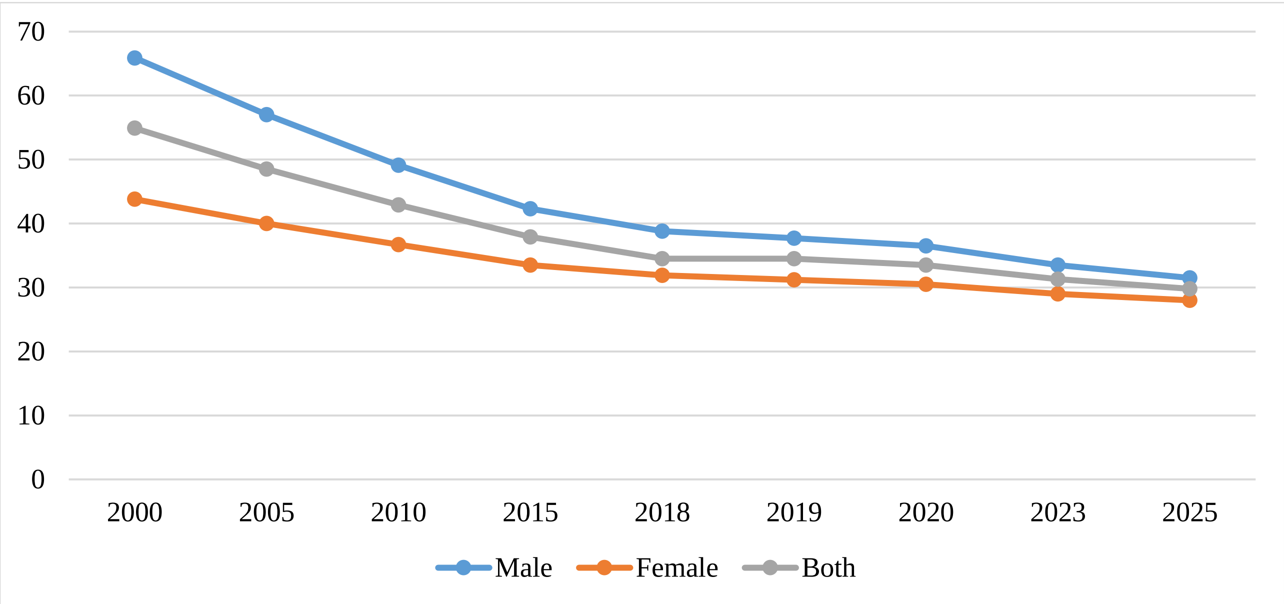


<u>***2019***</u>



Source: Own calculations based on data from Eurostat (2022).

Graph A.1.8: Age-standardized prevalence of current tobacco use among people aged ≥ 15 years, by gender, 2000-2025 estimates and projections



Source: WHO global report on trends in prevalence of tobacco smoking 2000-2025 (WHO, 2021a)

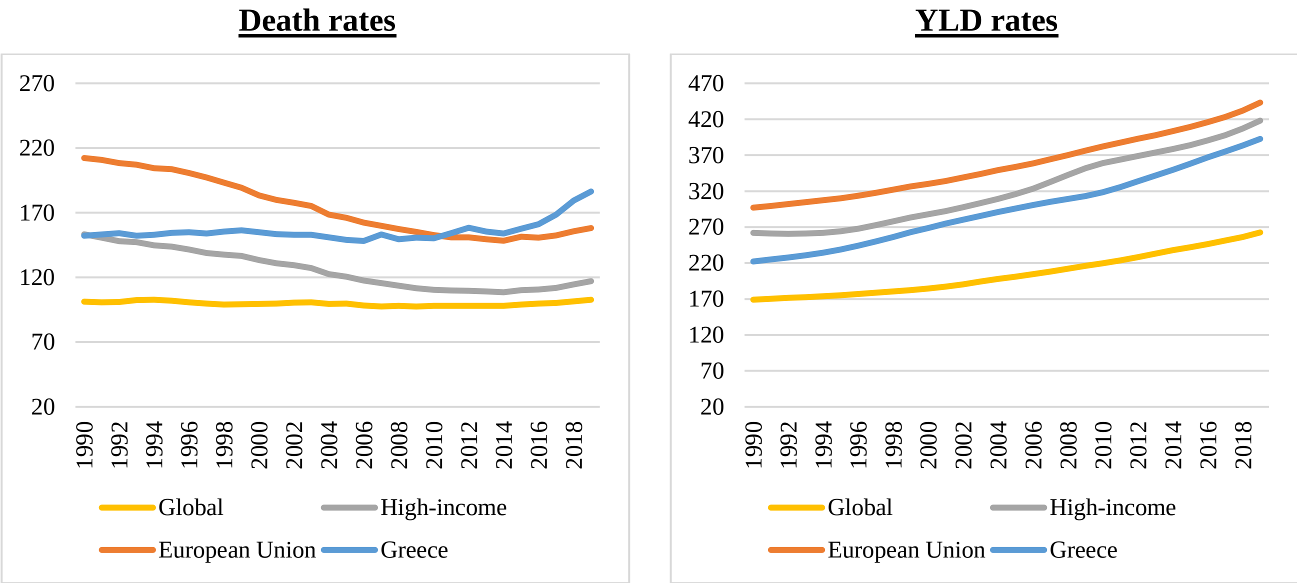
A.2 Health Outcome of Dietary Risks, Overweight/Obesity and Tobacco Use

Graph A.2.1: Risk factors, ranking by number of deaths and YLD per 100,000, both genders, all ages, Greece, 2019

Ranking by death rates	**Ranking by YLD rates**
1 High systolic blood pressure	1 Tobacco
2 Tobacco	2 High fasting plasma glucose
3 Dietary risks	3 High body-mass index
4 High fasting plasma glucose	4 Occupational risks
5 High LDL cholesterol	5 Dietary risks
6 High body-mass index	6 High systolic blood pressure
7 Kidney dysfunction	7 Alcohol use
8 Non-optimal temperature	8 Low bone mineral density
9 Air pollution	9 Child and maternal malnutrition
10 Alcohol use	10 Kidney dysfunction
11 Low physical activity	11 Air pollution
12 Other environmental risks	12 Drug use
13 Occupational risks	13 Childhood sexual abuse and bullying
14 Low bone mineral density	14 High LDL cholesterol
15 Unsafe sex	15 Low physical activity
16 Drug use	16 Intimate partner violence
17 Child and maternal malnutrition	17 Other environmental risks
18 Unsafe water, sanitation, and handwashing	18 Unsafe sex
19 Intimate partner violence	19 Unsafe water, sanitation, and handwashing
20 Childhood sexual abuse and bullying	

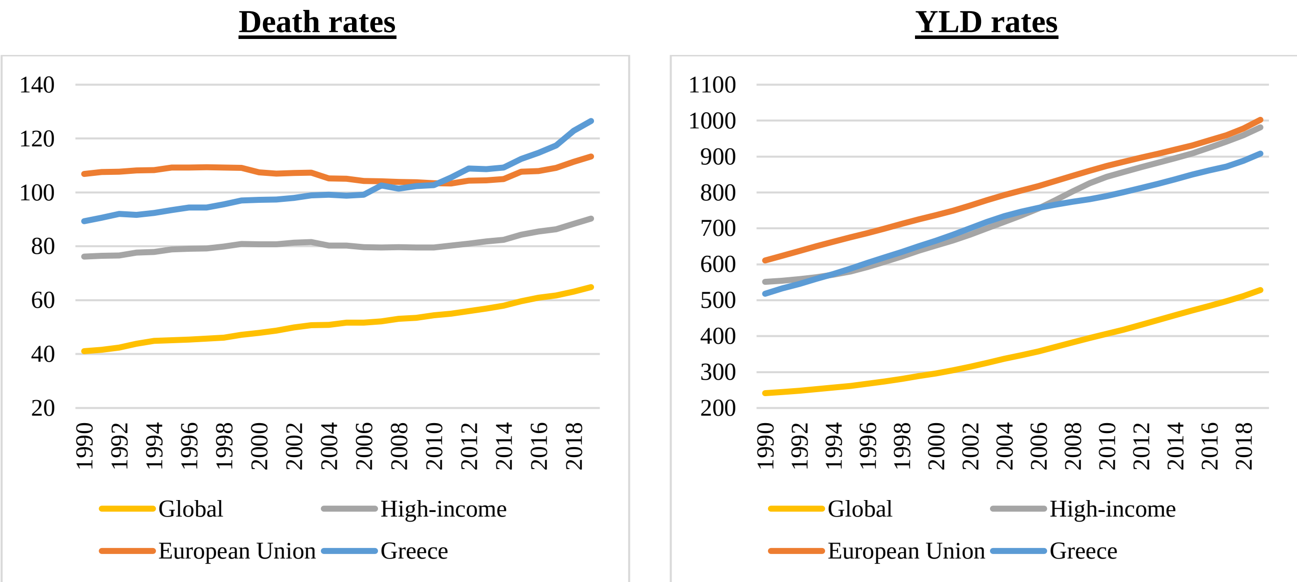
Source:2019 GBD study (Global Burden of Disease Collaborative Network, 2020)
Note: Risk factors are categorized into three categories. Purple fill is for behavioural risk factors; Ciel fill is for environmental/occupational risk factors; Salmon fill is for metabolic risk factors.

Graph A.2.2: Number of deaths and YLD related to dietary risks per 100,000, both genders, all ages, 1990-2019



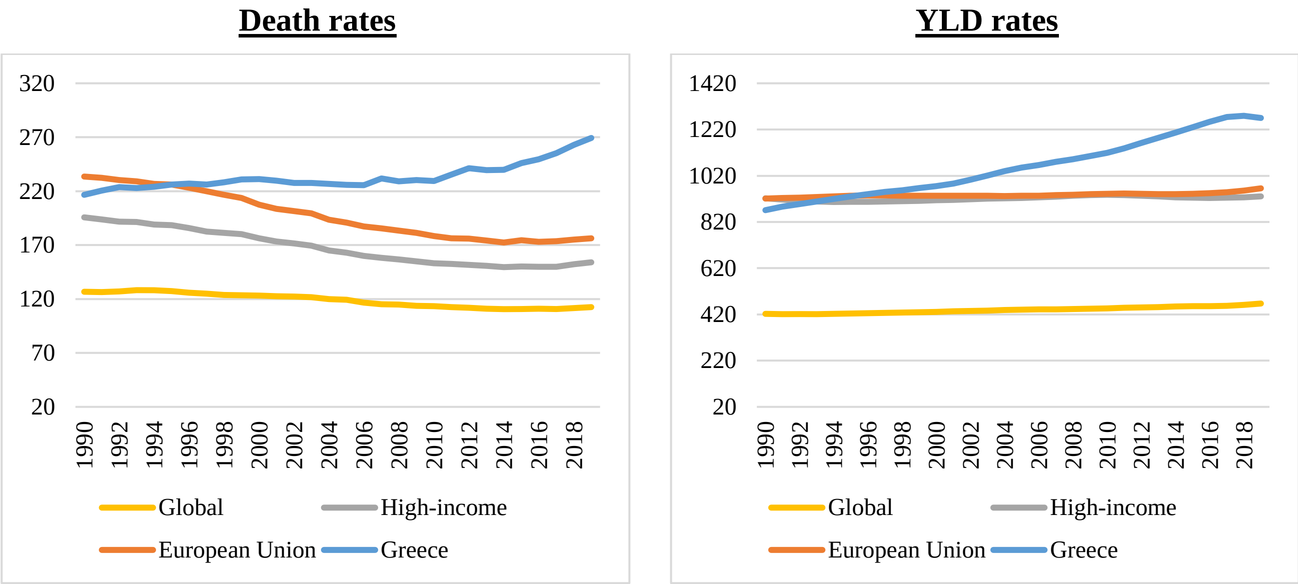
Source:2019 GBD study (Global Burden of Disease Collaborative Network, 2020)

Graph A.2.3: Number of deaths and YLD related to high BMI per 100,000, both genders, all ages, 1990-2019



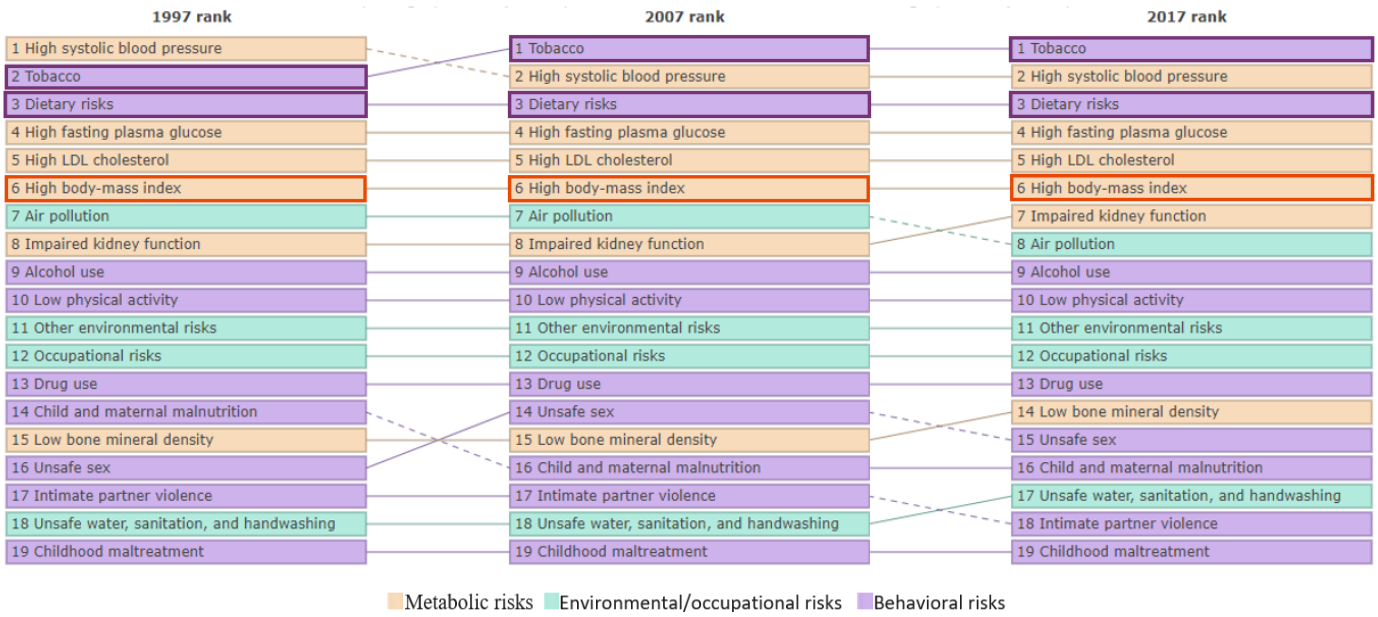
Source:2019 GBD study (Global Burden of Disease Collaborative Network, 2020)

Graph A.2.4: Number of deaths and YLD related to tobacco use per 100,000, both genders, all ages, 1990-2019



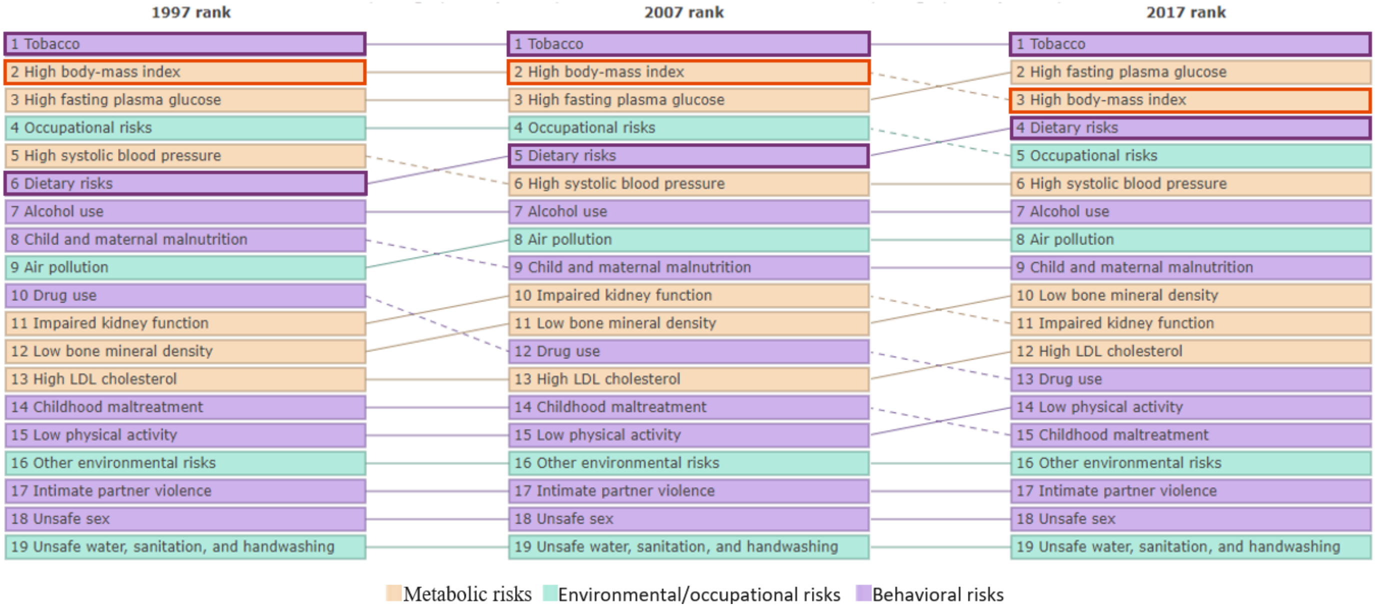
Source:2019 GBD study (Global Burden of Disease Collaborative Network, 2020)

Graph A.2.5: Risk factors, ranking by number of deaths per 100,000, both genders, all ages, Greece, a twenty-year comparison



Source: 2017 GBD study (Global Burden of Disease Collaborative Network, 2018)

Graph A.2.6: Risk factors, ranking by number of YLD per 100,000, both genders, all ages, Greece, a twenty-year comparison



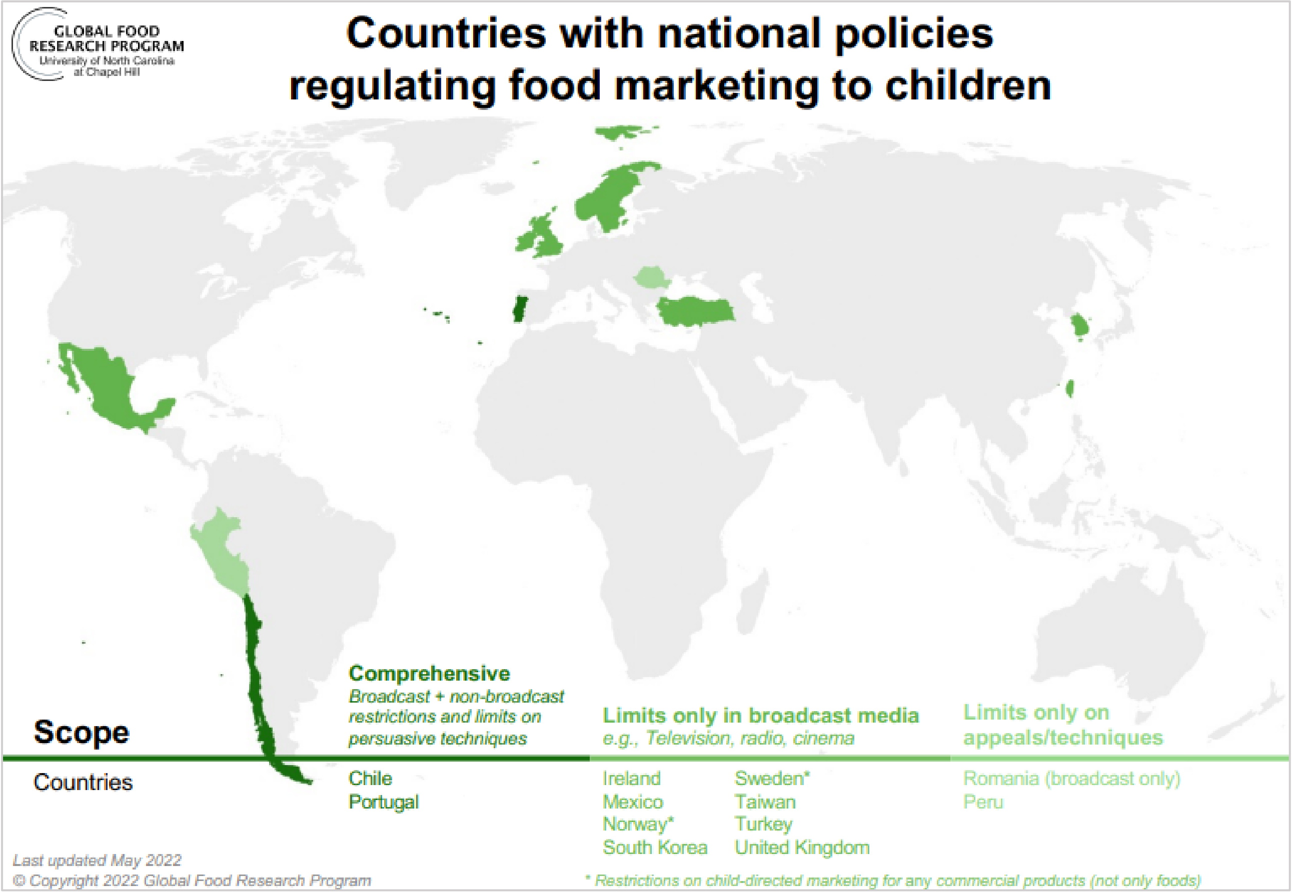
Source: 2017 GBD study (Global Burden of Disease Collaborative Network, 2018)

A.3 Policies on Healthy Eating and Obesity

Graph A.3.1: Countries with front-of-package labeling

Source: The Global Food Research Program (2022).
Notes: Last updated February 2022.
The map and further related information are available here.

Graph A.3.2: Countries with restrictions on marketing food to children

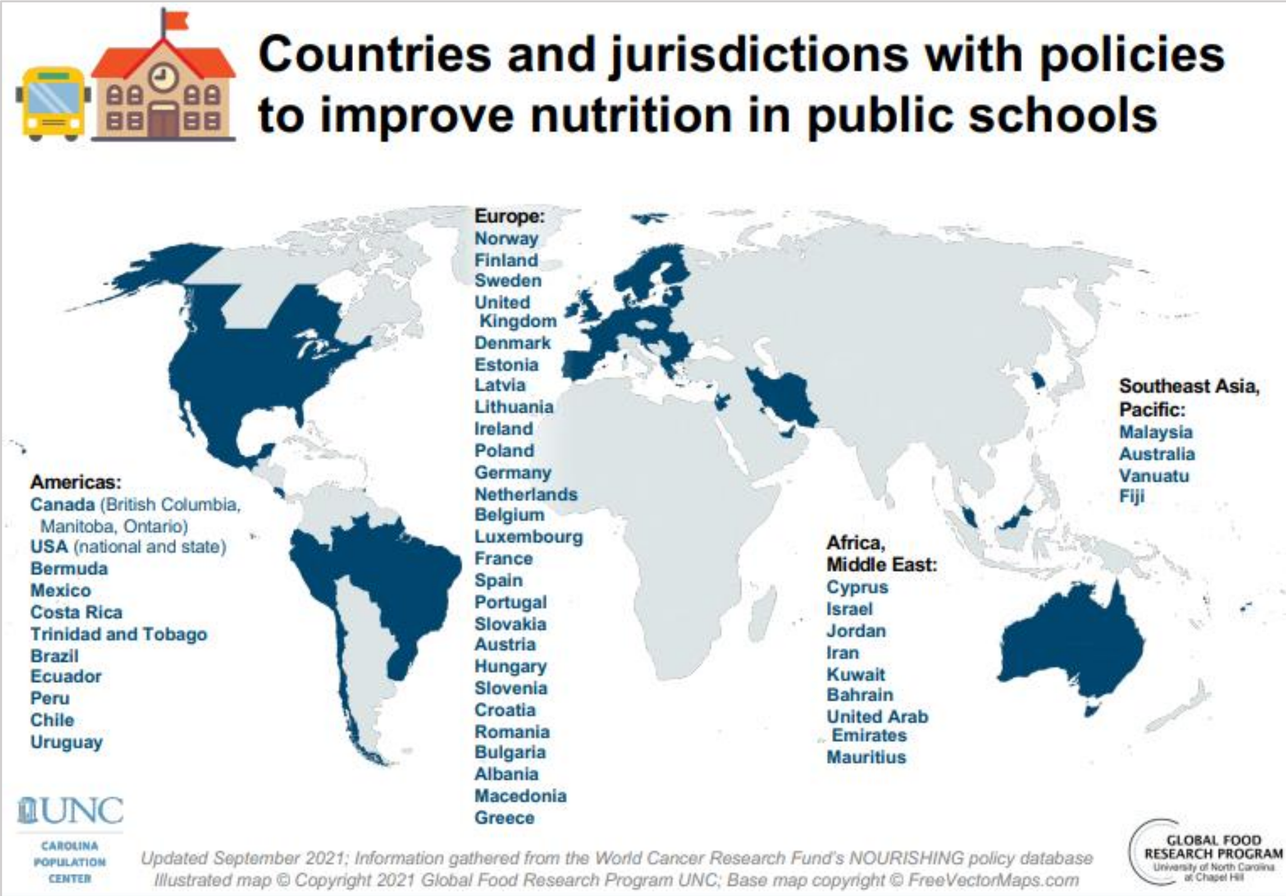


Source: The Global Food Research Program (2022).
Note: Last updated May 2022.
The map and further related information are available here.

Graph A.3.2: Countries with SSB taxes

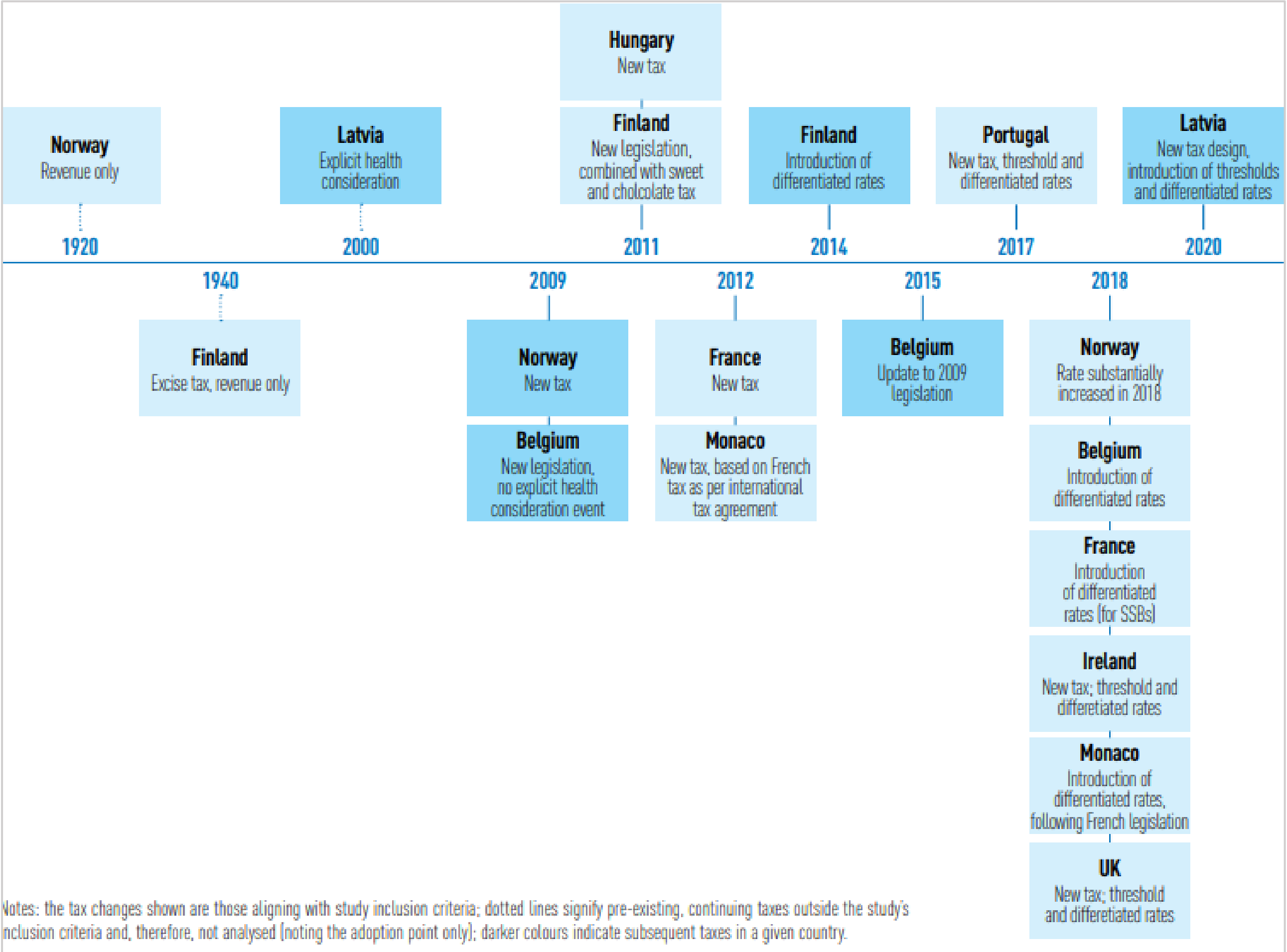
Source: The Global Food Research Program (2022).
Note: Last updated May 2022.
The map and further related information are available here.

Graph A.3.4: Countries with policies to improve nutrition in public schools



Source: The Global Food Research Program (2022).
Note: Last updated September 2021.
The map and further related information are available here.

Graph A.3.5: Timeline of initiation of SSB taxes in the WHO European Region



Source: WHO Regional Office for Europe (2022)

A.4 The Economic Cost Study

Table A.4.1: List of diseases for which mortality and morbidity were estimated

Cause	Smoking	SHS	High BMI	Dietary Risks
A. Communicable, maternal, neonatal, and nutritional diseases	√	√		
A.1 Respiratory infections and tuberculosis	√	√		
Tuberculosis	√			
Lower respiratory infections	√	√		
B. Non-communicable diseases	√	√	√	√
B.1 Neoplasms	√	√	√	√
Esophageal cancer	√		√	√
Stomach cancer	√			√
Liver cancer	√		√	
Gallbladder and biliary tract cancer			√	
Larynx cancer	√			√
Tracheal, bronchus, and lung cancer	√	√		√
Breast cancer (females only)	√	√	√	
Cervical cancer (females only)	√			
Prostate cancer (males only)	√			
Uterine cancer (females only)			√	
Ovarian cancer (females only)			√	
Colon and rectum cancer	√		√	√
Lip and oral cavity cancer	√			√
Nasopharynx cancer	√			√
Other pharynx cancer	√			√
Pancreatic cancer	√		√	
Kidney cancer	√		√	
Thyroid cancer			√	
Bladder cancer	√			
Non-Hodgkin lymphoma			√	
Multiple myeloma			√	
Leukemia	√		√	
B.2 Cardiovascular diseases	√	√	√	√
Ischemic heart disease	√	√	√	√
Stroke	√	√	√	√
Hypertensive heart disease			√	√
Atrial fibrillation and flutter	√		√	√
Aortic aneurysm (only for mortality)	√			√
Peripheral artery disease	√			√
Rheumatic heart disease				√
Cardiomyopathy and myocarditis				√
Endocarditis				√
Non-rheumatic valvular heart disease				√
Other cardiovascular and circulatory diseases				√

Table A.4.1: List of diseases for which mortality and morbidity were estimated (continued)

Cause	Smoking	SHS	High BMI	Dietary Risks
B. Non-communicable diseases (continued)	√	√	√	√
B.3 Chronic respiratory diseases	√	√	√	
Chronic obstructive pulmonary disease	√	√		
Asthma	√		√	
B.4 Digestive diseases	√		√	
Upper digestive system diseases	√			
Gallbladder and biliary diseases	√		√	
B.5 Neurological disorders	√		√	
Alzheimer's disease and other dementias	√		√	
Parkinson's disease	√			
Multiple sclerosis	√			
B.6 Diabetes and kidney diseases	√	√	√	√
Diabetes mellitus	√	√	√	√
Chronic kidney disease			√	√
B.7 Musculoskeletal disorders	√		√	
Rheumatoid arthritis	√			
Osteoarthritis (only for morbidity)			√	
Low back pain (only for morbidity)	√		√	
Gout (only for morbidity)			√	
B.8 Sense organ diseases	√		√	
Blindness and vision impairment (only for morbidity)	√		√	
C. Injuries	√			
Transport injuries	√			
Unintentional injuries	√			
Self-harm and interpersonal violence	√			

Disease categories as reported in 2017 GBD study (Global Burden of Disease Collaborative Network, 2018).

A.5 The Fiscal Policy Study

Table A.5.1: The thirteen good categories and their sub items

Bread, cereals & flour	
01112	Flours and other cereals
01113	Bread
01114	Other bakery products
01115	Pizza and quiche
01117	Breakfast cereals
Potatoes, pasta & rice	
01111	Rice
01174	Potatoes
01116	Pasta products and couscous
Meat	
01121	Beef and veal (fresh, chilled or frozen)
01122	Pork (fresh, chilled or frozen)
01123	Sheep and goat (fresh, chilled or frozen)
01124	Poultry (fresh, chilled or frozen)
Fish & seafood	
01131	Fresh or chilled fish
01132	Frozen fish
01133	Fresh or chilled seafood
01134	Frozen seafood
Milk products & eggs	
01141	Whole milk fresh
01142	Low fat milk fresh
01143	Preserved milk
01144	Yoghurt
01145	Cheese and curd
01147	Eggs
Vegetable oils & fats	
01152	Margarine and other vegetable fats
01153	Olive oil
01154	Other edible oils

Table A.5.1: The thirteen good categories and their sub items (continued)

Fruits	
01161	Fresh or chilled fruit
Vegetables	
01171	Fresh or chilled vegetables other than potatoes and other tubers
01172	Frozen vegetables other than potatoes and other tubers
01173	Dried vegetables, other preserved or processed vegetables
Sweets	
01181	Sugar
01182	Jams, marmalades and honey
01183	Chocolate
01184	Confectionery products
01185	Edible ices and ice creams
Soft drinks, juices & water	
01221	Mineral or spring waters
01222	Soft drinks
01223	Fruit and vegetables juices
Coffee & tea	
01211	Coffee
01212	Tea
Alcoholic drinks	
02111	Spirits and liqueurs
02121	Wine from grapes
02131	Lager Beer
Other unhealthy goods	
01191	Sauces, condiments
01192	Salt, spices and culinary herbs
01163	Dried fruits and nuts
01175	Crisps
01146	Other milk products
01151	Butter
01127	Dried, salted or smoked meat
01135	Dried, smoked or salted fish and seafood

Note: Codes of goods are as reported on the 2019 HBS (ELSTAT, 2020).

Table A.5.2: Density units for liquid goods

Code	*Food name*	*Density in g/ml*
01141	Milk, whole, fresh	1.031
01142	Milk, low fat, fresh	1.034
01143	Milk, preserved	1.064
01153	Olive oil	0.918
01154	Other edible oils	0.941
01221	Mineral or spring waters	1.035
01222	Soft drinks	1.028
01223	Fruit and vegetable juices	1.060
02111	Spirits and liqueurs	0.939
02121	Wine from grapes	0.993
02131	Lager beer	1.008

Source: Charrondiere et al. (2012)
Note: Conversion factor for "other edible oils" is the average of 0.960 and 0.922 which are the conversion factors for sunflower oil and corn (maize) oil, respectively.

Table A.5.3: Results of unit value regressions

	Bread, cereals & flour	*Potatoes, pasta & rice*	*Meat*	*Fish & seafood*	*Milk products & eggs*	*Veg. oils & fats*	*Fruits*	*Vege-tables*	*Sweets*	*Soft drinks juices & water*	*Coffee & tea*	*Alcoholic drinks*	*Other unhealthy goods*
Log of expenditure	0.037***	0.078***	0.031***	0.036***	0.096***	0.019***	0.072***	0.035***	0.016***	0.040***	0.023***	0.031***	0.021***
Log of hh size	-0.087***	-0.021*	0.010**	0.005	0.101***	-0.005	-0.007	-0.078***	0.003	0.034***	-0.017*	-0.020**	-0.004
Age of the head of hh	0.001***	-0.001**	0.000***	0.000***	0.002***	0.000	0.000	0.000	0.000	0.000	-0.021***	0.000	0.000
% of dependent mbs	0.049***	-0.003	0.029***	0.015	-0.052**	0.012	0.029	0.032	0.009	0.035*	-0.030	0.022	0.000
% of mbs with income	-0.003	0.035*	0.021**	0.001	0.025	-0.003	0.002	0.038*	0.019*	0.012	-0.043**	-0.016	-0.005
Gender female	0.003	0.007	-0.013***	0.003	0.002	-0.010**	0.027**	-0.009	-0.004	-0.001	0.013	0.006	-0.003
Education Level 2	-0.005	-0.001	0.003	-0.006	0.002	-0.019*	0.006	-0.002	-0.009	0.013	-0.015	-0.009	0.009
Education Level 3	-0.004	0.001	-0.004	0.003	0.012	-0.030***	0.023	-0.014	-0.005	-0.004	0.086	0.007	0.006
Education Level 4	0.005	0.010	-0.003	0.002	0.027*	-0.022**	0.031	-0.007	0.001	0.016	-0.047	-0.014	0.011
Education Level 5	-0.008	0.036	0.011	0.009	0.051**	-0.002	0.036	0.002	0.020*	0.008	0.022	0.019	0.006
Education Level 6	0.037***	0.031	0.014*	0.014*	0.063***	-0.010	0.065***	0.005	0.011	0.030*	0.046	-0.009	0.017**
Education Level 7	0.040**	0.019	0.020*	0.035***	0.085***	-0.025*	0.127***	0.038	0.030**	0.047*	0.012	0.062**	0.044***
Constant	1.211***	-0.222***	1.600***	1.824***	0.365***	1.377***	-0.516***	0.521***	2.059***	-0.373***	3.176***	2.062***	2.123***
R-squared	0.445	0.273	0.361	0.760	0.211	0.345	0.120	0.237	0.578	0.472	0.464	0.528	0.689

Notes: hh = household; mbs=members; level 2 = Complete primary education; level 3 = Complete lower secondary education; level 4 = Upper secondary education; level 5 = Post-secondary non tertiary education; level 6 = Short cycle tertiary, Bachelor or equivalent; level 7 = Higher level of education; *p<0.05, **p<0.01, ***p<0.001.

Table A.5.4: Results of budget share regressions

	Bread, cereals & flour	*Potatoes, pasta & rice*	*Meat*	*Fish & seafood*	*Milk products & eggs*	*Veg. oils & fats*	*Fruits*	*Vege-tables*	*Sweets*	*Soft drinks juices & water*	*Coffee & tea*	*Alcoholic drinks*	*Other unhealthy goods*
Log of expenditure	-0.016***	-0.007***	-0.017***	-0.002***	-0.019***	-0.007***	-0.007***	-0.014***	-0.001**	-0.002***	-0.003***	0.004***	-0.002***
Log of hh size	-0.004***	-0.002***	0.005***	0.001*	-0.009***	-0.006***	-0.004***	-0.006***	-0.001	0.000	-0.002***	-0.001**	0.000
Age of the head of hh	0.000	0.000*	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	-0.000**	0.000	-0.000***	-0.000
% of dependent mbs	0.004*	-0.001*	-0.012***	-0.005***	0.007***	-0.000	0.001	-0.008***	0.004**	0.002**	-0.001*	-0.007***	-0.000
% of mbs with income	-0.001	-0.000	-0.002	-0.004***	-0.003*	-0.002	-0.001	-0.004***	-0.002*	0.001	-0.006	-0.001	0.001
Gender female	0.001	0.000	0.000	0.000	0.003***	0.001*	0.001*	0.002***	0.001***	0.000	0.001	-0.002***	0.000
Education Level 2	0.002	-0.001*	0.003	0.002*	0.000	-0.000	0.001	0.002*	-0.000	-0.000	0.001	-0.000	0.002*
Education Level 3	-0.000	-0.001	0.002	0.002	-0.002	0.000	-0.000	0.002	0.001	-0.000	0.002	-0.000	0.003**
Education Level 4	-0.001	-0.002***	0.000	0.003**	-0.001	-0.000	0.000	0.002	0.000	-0.000	0.003	-0.001	0.002**
Education Level 5	-0.001	-0.001*	-0.002	0.002	-0.001	-0.003*	0.001	0.002	0.001	-0.001	0.003	-0.001	0.003***
Education Level 6	-0.002	-0.002***	0.001	0.003***	0.000	-0.002*	0.001	0.001	-0.000	0.000	0.006	-0.000	0.003***
Education Level 7	-0.002	-0.002*	0.001	0.003*	0.002	-0.003	0.001	0.002	0.001	0.001	0.007	0.000	0.001
Constant	0.178***	0.075***	0.172***	0.022***	0.200***	0.073***	0.074***	0.140***	0.019***	0.025***	0.033***	-0.004	0.033***
R-squared	0.282	0.309	0.220	0.129	0.299	0.189	0.240	0.305	0.053	0.110	0.135	0.135	0.079

Notes: hh = household; mbs=members; level 2 = Complete primary education; level 3 = Complete lower secondary education; level 4 = Upper secondary education; level 5 = Post-secondary non tertiary education; level 6 = Short cycle tertiary, Bachelor or equivalent; level 7 = Higher level of education; *p<0.05, **p<0.01, ***p<0.001.

Table A.5.5: Standard errors of own and cross-price elasticities (estimated with the bootstrap approach)

	Bread, cereals & flour	*Potatoes, pasta & rice*	*Meat*	*Fish & seafood*	*Milk products & eggs*	*Veg. oils & fats*	*Fruits*	*Vegetables*	*Sweets*	*Soft drinks juices & water*	*Coffee & tea*	*Alcoholic drinks*	*Other unhealthy goods*
Bread, cereals & flour	0.010	0.000	0.006	0.005	0.007	0.005	0.011	0.008	0.005	0.012	0.008	0.013	0.005
Potatoes, pasta & rice	0.004	0.007	0.003	0.004	0.003	0.010	0.005	0.003	0.006	0.007	0.006	0.004	0.004
Meat	0.000	0.006	0.013	0.007	0.013	0.012	0.006	0.016	0.012	0.015	0.007	0.020	0.007
Fish & seafood	0.014	0.022	0.000	0.005	0.004	0.005	0.004	0.002	0.008	0.003	0.004	0.005	0.002
Milk products & eggs	0.007	0.006	0.009	0.005	0.009	0.006	0.005	0.006	0.007	0.013	0.007	0.007	0.000
Vegetable oils & fats	0.010	0.005	0.011	0.014	0.000	0.013	0.005	0.005	0.008	0.005	0.008	0.015	0.008
Fruits	0.006	0.010	0.011	0.014	0.008	0.000	0.007	0.004	0.004	0.005	0.004	0.003	0.015
Vegetables	0.009	0.011	0.004	0.008	0.008	0.005	0.000	0.008	0.004	0.005	0.004	0.006	0.007
Sweets	0.011	0.003	0.007	0.005	0.010	0.011	0.006	0.000	0.006	0.004	0.003	0.004	0.007
Soft drinks, juices & water	0.004	0.003	0.002	0.006	0.002	0.004	0.006	0.005	0.003	0.004	0.000	0.003	0.003
Coffee & tea	0.003	0.006	0.009	0.006	0.008	0.007	0.008	0.004	0.000	0.002	0.003	0.003	0.003
Alcoholic drinks	0.003	0.003	0.004	0.002	0.003	0.003	0.005	0.005	0.011	0.000	0.004	0.003	0.007
Other unhealthy goods	0.007	0.006	0.005	0.000	0.003	0.004	0.004	0.006	0.003	0.005	0.007	0.003	0.005

Note: Standard errors are obtained from 1,000 bootstrap replications.

Table A.5.6: Mean annual expenditure, purchased and with all modes of acquisition, by category

Category	***Expenditure purchased***	***Expenditure with all modes of acquisition***	***% difference***
Bread, cereals and flour	194.98	198.96	2.04%
Potatoes, pasta and rice	67.29	74.33	10.46%
Meat	274.47	306.01	11.49%
Fish and seafood	96.96	100.12	3.26%
Milk products and eggs	242.25	260.27	7.44%
Vegetable oils and fats	91.89	115.00	25.15%
Fruits	100.70	112.33	11.56%
Vegetables	171.71	199.58	16.23%
Sweets	81.17	87.36	7.62%
Soft drinks, juices and water	42.68	43.56	2.08%
Coffee and tea	42.55	43.38	1.95%
Alcoholic drinks	89.98	94.40	4.92%
Other unhealthy goods	95.45	97.82	2.49%

Source: Own calculations, based on data from the 2019 HBS (ELSTAT, 2020).