UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Sustainable consumption: fiscal policies and household behaviour

By
Wisdom Dogbe

Doctoral Research in Sustainability

University Polytechnic of Catalonia

Barcelona TECH

SUSTAINABLE CONSUMPTION: FISCAL POLICIES AND HOUSEHOLD BEHAVIOUR

Doctoral Thesis Presented

By

Wisdom Dogbe

Director:
Dr. José María Gil Roig

June, 2019

SUMMARY

The aim of this thesis is to investigate the influence of climate and health policies on personal well-being (personal ecology) and the environment (ecological context) as well as how household behaviour influences the sustainability of health goals – prevalence of obesity. The most important contribution of this thesis is the application of new methods, use of experimental data and incorporation of national climate and health policy goals into our analysis. The thesis is divided into six chapters, the first chapter deals with the introduction of the thesis whilst the last chapter summarizes the conclusion from the four main chapters comprising of four papers.

The second Chapter (first paper) investigates the effectiveness of carbon tax to promote climate-friendly food demand, welfare and diet quality in Spain. Tax policy scenarios were based on EU alternative social cost of emissions. Own- and cross-price elasticities of sixteen food groups were calculated from incomplete Exact Affine Stone Index (EASI) food demand system. Results show that price increases due to the tax reform reduces the consumption of the food products associated with higher CO_2 equivalent emissions but improves diet quality i.e. the consumption of health improving foods. Even though the tax reform simultaneously improved both the environment and health, the tax was more regressive on low-income citizen's welfare.

Whiles the second chapter was targeted at both environmental and health goals, the third Chapter (second paper) investigates the effectiveness of a health tax reform on consumer welfare and diet quality. In this case, the tax policy scenario was based on internalizing the social cost of obesity in Spain. Static household panel data collated in 2012 in Catalonia was applied to an EASI demand model to estimate nutrient price and expenditure elasticities were estimated. Results suggest marginal improvement in the quality of diet, although not in the very short term. Moreover, the consumption of health damaging nutrients such as saturated fatty acid, sodium, and cholesterol decreased tremendously. From the welfare perspective, the tax policy is not regressive for all household segments.

In Chapter four (third paper) the thesis took a behavioural perspective due to the marginal impact of the taxes on reducing the consumption of both environmental and health damaging foods. As a result this chapter assessed the link between psychological attitudes such as risk attitudes, time inconsistencies and body mass index (to account for the prevalence of obesity) in Catalonia. Experimental data on consumer attitudes towards risk, time inconsistencies and socio-demographic characteristics were collated from a section of Catalonian households in 2014. Econometric approach were based on Tanaka et al. (2010) – prospect theory and Benhabib et al. (2010) – time discounting were used to estimate the risk and time parameters, respectively. The results support a strong influence of risk aversion on the development of body mass index. Furthermore, time inconsistencies significantly influence individuals propensity to increase body mass index.

The fifth Chapter (fourth paper) brings together all the covariates that influence the development of obesity by investigating the psychological, behavioural and socioeconomic drivers of obesity in Catalonia using path model analysis. Experimental data that elicited risk preferences, time inconsistencies, believes about obese persons, attitudes towards obesity, body perception, body image dissatisfaction and body mass index consumers were used. A multivariate path modelling was used to estimate the path parameters linking the covariates. Results suggest significant direct and indirect relationships between obesity and most variables. First, obesity is directly influenced by believe that obesity is under the control of people with obesity, correct body image and body image dissatisfaction. Second, significant indirect relationship was found between obesity and attitudes towards persons with obesity.

Socioeconomic factors that have significant influence of obesity include age and gender. Risk attitudes did not have any direct or indirect effects on obesity. Government should consider the interactions that exist among the various drivers of obesity when formulating obesity related policies.

RESUMEN

El objetivo de esta tesis doctoral es investigar la influencia de la implementación simultánea de políticas climáticas y de salud sobre el bienestar personal (ecología personal) y el medioambiente (contexto ecológico), así como, la forma en que el comportamiento de los hogares influye en la sostenibilidad de los objetivos de salud – prevalencia de obesidad. La contribución principal de esta tesis es la aplicación de nuevas metodologías, el uso de datos experimentales y la incorporación de los objetivos de políticas nacionales de clima y salud en nuestro análisis. El presente documento se divide en seis capítulos, el primero consiste en una introducción a la temática, los cuatro siguientes, donde se desarrollan los contenidos, corresponden a las publicaciones científicas, mientras que el último recoge las conclusiones de los capítulos anteriores.

El segundo capítulo (primera publicación científica) investiga la efectividad del impuesto sobre las emisiones de carbono en la promoción de la demanda de alimentos medioambientalmente sostenibles, bienestar social y calidad de la dieta en España. Se han diseñado diferentes escenarios de políticas de impuestos basados en las alternativas de costes de emisiones de la Unión Europea (UE). Las elasticidades propias y cruzadas de los precios de dieciséis grupos de alimentos se han calculado a partir del sistema de demanda de alimentos "Exact Affine Stone Index (EASI)". Los resultados obtenidos muestran que el aumento de precios producido por la reforma de impuestos conlleva a una reducción del consumo de alimentos asociados con mayores emisiones de CO_2 equivalente, a la vez que mejora la calidad de la dieta; por ejemplo, el consumo de alimentos saludables. Aunque se observa que la reforma de los impuestos mejora simultáneamente la salud y el medioambiente, esta parece afectar en mayor grado a segmentos de población con bajos recursos y niveles de bienestar.

El tercer capítulo (segunda publicación científica), a diferencia del segundo que se centra en el medioambiente y la salud, investiga la efectividad de la reforma de los impuestos en el bienestar y la calidad de la dieta de los consumidores. En este caso, el escenario de política de impuestos se basa en internalizar el coste social de la obesidad en España. Para estimar el precio de los nutrientes y las elasticidades de gasto de la compra de los hogares se utilizan los datos del panel de hogares de Cataluña recolectados en el 2012 aplicados a un modelo de demanda EASI. Los resultados sugieren una mejora marginal de la calidad de la dieta, aunque ésta no se observa a corto plazo. Además, el consumo de nutrientes dañinos para la salud como ácidos grasos saturados, sodio y colesterol, disminuyen enormemente. Desde el punto de vista de bienestar, el régimen neutral de los impuestos afecta a hogares de todas las clases sociales.

En el capítulo cuatro (tercera publicación científica), debido al impacto marginal de la reforma de los impuestos en la reducción del consumo de alimentos dañinos tanto para el medioambiente como para la salud, la tesis adopta una perspectiva de comportamiento de los hogares. Como resultado, este capítulo evalúa el vínculo entre las actitudes psicológicas como las actitudes de riesgo, las inconsistencias temporales y el índice de masa corporal (para tener en cuenta la prevalencia de la obesidad) en Cataluña en 2014. El enfoque econométrico se basa en Tanaka et al. (2010) - la teoría de la perspectiva y Benhabib et al. (2010) – el descuento de tiempo- ambos se utilizan para estimar los parámetros de riesgo y tiempo, respectivamente. Los resultados apoyan una fuerte influencia de la aversión al riesgo en el desarrollo del índice de masa corporal. Además, las inconsistencias de tiempo influyen significativamente en la propensión de los individuos a aumentar el índice de masa corporal.

El quinto capítulo (cuarto artículo) reúne a todas las covariables que influyen en el desarrollo de la obesidad mediante la investigación de los factores psicológicos, de comportamiento y socioeconómicos de la obesidad en Cataluña mediante el análisis de modelos de diagramas causales. Se utilizaron datos experimentales de consumidores para identificar sus preferencias de riesgo, inconsistencias temporales, creencias sobre las personas obesas, actitudes hacia la obesidad, percepción corporal, insatisfacción con la imagen corporal e índice de masa corporal. Se utilizó un modelo multivariado de diagramas causales para estimar los vínculos entre las diferentes covariables. Los resultados sugieren que existen relaciones significativas directas e indirectas entre la obesidad y la mayoría de las variables. En primer lugar, se observó que la obesidad está directamente influenciada por la creencia que está bajo el control de la gente que la padece, que tiene una imagen corporal correcta y la gente que sufren insatisfacción de su imagen corporal. En segundo lugar, se encontró una relación indirecta significativa entre la obesidad y las actitudes hacia las personas obesas. Los factores socioeconómicos que tienen una influencia significativa en la obesidad incluyen la edad y el género. En cambio, las actitudes de riesgo no tuvieron ningún efecto directo o indirecto sobre la obesidad. El gobierno debe considerar las interacciones que existen entre los diversos determinantes de la obesidad al formular políticas relacionadas con la esta.

DEDICATION

I dedicate this work to my amazing wife:

Mrs. Janet Pomah Dogbe

ACKNOWLEDGMENT

My ultimate gratitude goes to the Almighty God for His mercies, kindness, favor, and grace to me from the beginning to the completion of this work.

I am very grateful to my supervisor, Prof. Jose Maria Gil Roig, for consistently setting aside the time and patience needed to guide me through my research work. Without his generous devotion, addition of valuable, constructive, and objective comments, successful accomplishment of this work would not have been met. I am indebted to him for his kindness and tireless efforts that enabled me to finalize this thesis.

My most profound appreciation goes to my parents, Mr. and Mrs Dogbe (Ghana) for their support and efforts in making my dream come true. Special thanks to my siblings: Emmanuel Dogbe, Gabriel Dogbe, Gladys Dogbe, Esther Dogbe and Florence Dogbe for their diverse contributions to my life and the man I am becoming.

Finally, I am grateful to colleagues of the CREDA-UPC-IRTA for their encouragement and invaluable contributions; I appreciate my family and good friends, D’ness Dr. Florence Nimoh and Benjamin Adjei Freeman for their support and encouragement towards the successful completion of my work.

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CHAPTER 1
INTRODUCTION

1.1 Background

Food consumption has a major implication for the environment, individual and public health, social cohesion, and the economy as a result playing an important role in sustainable consumption and production policy goals (Reisch et al., 2013). Food consumption in western societies have been labelled to be unsustainable due to the recent soaring rates in non-communicable diseases and environmental problems – climate change (Commission and others, 2009). Cited environmental problems associated with unsustainable consumption include climate change, water pollution, water scarcity, soil degradation, eutrophication of water bodies, and loss of habitats and biodiversity (Reisch et al., 2013). Similarly, diet- and lifestyle-related health problems associated with unsustainable consumption behaviour include non-communicable diseases such as cardiovascular diseases and diabetes (CEC, 2007) increasing public health costs (BCO, 2007), with social cohesion increasingly in danger because health is so closely related to socioeconomic status.

Since household consumption poses major danger to both climate and human health (Pape et al., 2011), two crucial aspects has been the focal point in the debate towards sustainable consumption: 1) the need for behavioural change; and 2) the role of government to positively influence policy towards more sustainable lifestyles (Jackson, 2009). However, efforts are largely minimal toward an integrated sustainable policies that tackle both environmental and health problems (Reisch, 2006). As such, economic policies based on the double food pyramid of Ruini et al. (2015) is in the right direction. To sum up, sustainable food policies should contribute towards reducing environmental degradation, while at the same time improving personal health.

However, economic policies are not without their own short falls as economic studies do not consider the confounding effect of behavioural attitudes (Dave and Saffer, 2008). The significance of this is underscored by the fact that unobserved heterogeneity across individuals account for the poor response to health and environmental policies. This heterogeneity is, generally, ignored in economic studies due to lack of data.

Environmental and nutritional fiscal policies such as taxes usually have short term impact on consumer behaviour (Cornelsen et al., 2014). Psychologists have therefore concluded that risk preferences and time inconsistency are important determinant of addictive behaviour (alcohol, smoking, unhealthy consumption) and the poor response to public policies. Addictive behaviours have usually been explained by psychologists using prospect theory (Kahneman and Tversky, 2013) or rational addiction theory (Becker and Murphy, 1988). However, economists have not been able to integrate behavioural attitudes into the study of food demand (Dave and Saffer, 2008).

Becker and Murphy (1988) proposed a theoretical model in which forward-looking, utility maximizing consumers may become addicted to the consumption of a good. Consumers are assumed to be rational because they anticipate the future consequences of current consumption. Consumers recognize the addictive nature of their choices but they may elect to make them because the expected gains from the activity exceed the costs through future addiction. From the prospect theory perspective, these consumers overweigh the loss from giving up consumption today more than the gain from not consuming the addictive good. Implying that addictive behaviour of consumers is driven by the aversion towards losses. In conclusion, health and environmental goals should incorporate these heterogeneous consumer behaviour (i.e. aversion to loss or risk or time preferences) to affect consumer choice (McGeevor, 2009). As such, there is the need to perform a holistic analysis by considering how consumers respond to environmental and nutritional taxes as well as analysis the psychological factors driving their unhealthy consumption.

1.2 Food Consumption Trends in Catalonia

Recommended Dietary Guidelines Based On Spanish/Catalan Food Pyramid

The food pyramid recommended by the Catalan health department – Canal Salut conforms to the proposed Spanish/Mediterranean diet pyramid. First, water and liquid foods are located at the base of the pyramid, promoting body hydration; 1.5–2 L/d of water is recommended. The base of the pyramid also incorporates family and physical activity. This therefore suggests that family and friends are one of the pillars of a healthy lifestyle. More importantly, performance of physical activity should be regularly, at a level that promotes a healthy weight.

Next to the base of the pyramid, cereals and their main derivatives (bread, pasta, etc.) are the significant energy sources along with potatoes, which are frequently used in side dishes in the Mediterranean diet. From 4 to 6 portions daily of these foods (1 portion = 60–68 g of pasta or rice or 40–60 g of bread), with at least one-half of these from whole-grain cereals, are recommended.

Fruits, vegetables, and related products occupy the next level. This is a diverse food group, including plant roots, bulbs, stems, leaves, flowers, and fruits, which are rich in dietary fibre and micronutrients, as well as bioactive compounds. At least 5 portions (1 portion = 150–200 g), with a minimum of 2 fresh portions, are recommended.

In the same group, virgin olive oil is considered as major source of dietary fat as well as other healthy unsaturated oils, namely rapeseed or colza, including canola, sunflower, and soybean oils, are considered as the dietary fat of preference not only as part of salad dressing but also for food cooking and frying. This group includes fresh olives, which are also rich in bioactive compounds and fibre. Daily consumption of 3 to 5 portions (1 portion = 10 mL) is recommended.

The fourth level contains milk (i.e., low-fat milk) and dairy products, particularly fermented milk and cheese, which provide protein of a very high quality, as well as calcium and other minerals and vitamins; the recommended intake for this type of food is 2–3 portions daily (1 portion = 200–250 mL of milk, 200–250 g of yogurt, or 80 g of fresh cheese).

On the sixth level, the consumption of 2–3 portions daily of protein-rich foods of animal origin (range: 60–150 g), including poultry and other white meats, eggs and fish, as well as plant-based protein-rich foods, namely legumes and nuts, is recommended. These foods, which provide not only protein but also many micronutrients and a number of PUFAs, should be consumed by alternating them in main dishes during the week.

The next level after white meat and plant protein are red meats, high-fat products. These are optional foods that should be consumed occasionally and moderately. Wine plays a moderate role in daily consumption, and it is widely accepted that ∼1 glass/d of red wine (150–200 mL) might be beneficial mainly due to its relatively high amounts of polyphenols.

At the vertex of the triangle are sweets, and other sugar-enriched products which must be consumed occasionally. Salt has relatively low importance in Mediterranean diet. In addition to the relative high consumption of fruits and vegetables, the wide use of spices and herbs in the preparation of meals provides a way to reduce the daily intake of salt.

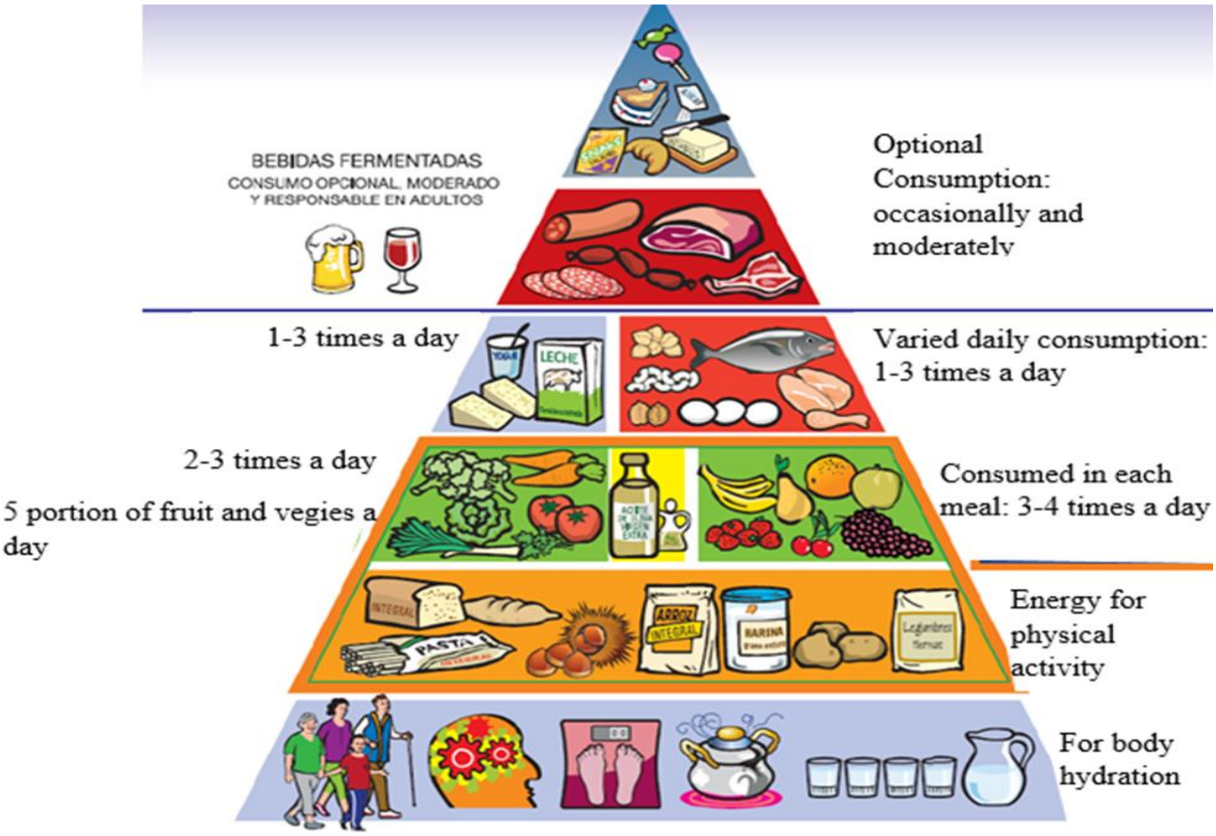

Figure 1-1 Spanish/Catalan/Mediterranean Food Pyramid (source: NAOS Strategy, 2019)

Double Pyramid: Food and environmental pyramids

The Mediterranean/Spanish diet pyramid does not offer only considerable health benefits but also respect the environmental ecology. The double food pyramid was designed by the Barilla Centre for Food and Nutrition (BCFN, 2014) based on the Mediterranean (recommended Spanish/Catalan) diet in order to assess the simultaneous impact that food has on human health and the environment. The Double Pyramid in Figure 1-2 suggest that those foods with higher recommended consumption levels (see Figure 1-1) are also those with lower environmental impact.

This suggest that these food groups can also be evaluated in terms of their environmental impact. Reclassifying foods no longer in terms of their positive impact on health, but on the basis of their negative effect on the environment, produces an up-side-down pyramid of Figure 1-1. The new pyramid shows that those foods with greater environmental impact are on the top and those with lower impact are on the bottom.

When this new environmental pyramid is brought alongside the Mediterranean diet pyramid, it creates a food-environmental pyramid called the “Double Pyramid”. This unified model shows that if the diet suggested in the Mediterranean food pyramid is followed, not only people do live better, but there is a decidedly less impact or better footprint left on the environment (BCFN, 2014). Therefore, human beings, through eating responsibly, can definitely reconcile their personal well-being (personal ecology) with the environment (ecological context).

In 2010, the Food and Agriculture Organization (FAO) together with Biodiversity International emphasized the importance of "sustainable diets," thus acknowledging the close link between human health and that of our ecosystems (Gold and McBurney, 2010). For instance, in European countries such as Germany and UK, national agencies and NGOs are promoting "Sustainable Dietary Guidelines" in an attempt to reconcile nutritional advice with environmental concerns (Ruini et al., 2015).

These guidelines suggest that high adherence to the Mediterranean diet depicted by the food pyramid can lead to significant health benefits, including a reduction in non-communicable diseases associated with obesity (Keys, 1980)

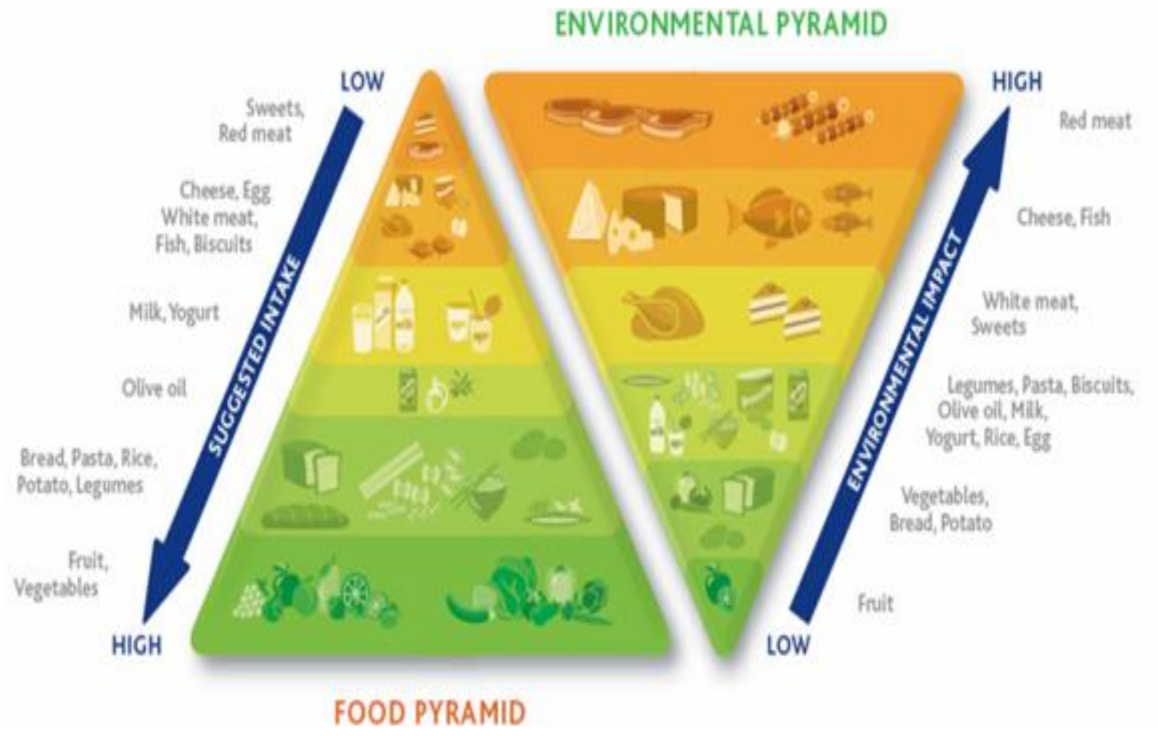

Figure 1-2 Double Pyramid (Source: Barilla Centre for Food and Nutrition, 2014)

Current dietary pattern in Catalonia

Catalonia has not been exempted from the changes in dietary habits that have affected developed countries (Serra-Majem et al., 2007). Current diet is characterized by a decrease in fruit consumption as well as in vegetables, chicken, fish (whitefish and seafood), and offal towards dairy product, low fat and skim milk derivatives consumption (Ribas-Barba et al., 2007). Valdés et al. (2009) also found that energy density and intake of total, saturated, monounsaturated and vegetable fat were significantly higher among a section of Catalonians interviewed in 2005 compared to 2000. In addition, compliance to Spanish Society of Community Nutrition (SENC) Healthy Eating dietary guidelines – Spanish Food Pyramid was found to be low in Catalonia among subjects interviewed between 2002-2003 (Serra-Majem et al., 2007). In conclusion, current diets are characterized by higher intakes of animal proteins, processed foods, hydrogenated fats, and a lower intake of fibre (depicting an inverse food pyramid as shown on Figure 1-3).

A study by Serra-Majem et al. (2007) in Catalonia has confirmed the suspicion of nutritional transition away from the recommended Mediterranean. First, Serra-Majem et al.'s results showed that animal protein is consumed in excess. Thirty percent of the Catalan population did not comply with the recommendation for fish consumption, 68% exceeded the recommended meat/protein intake and 7% exceeded the recommended egg intake.

In addition, Sixty-three percent did not meet the recommendation for pulses and 74% showed noncompliance with the recommendation for nut consumption.

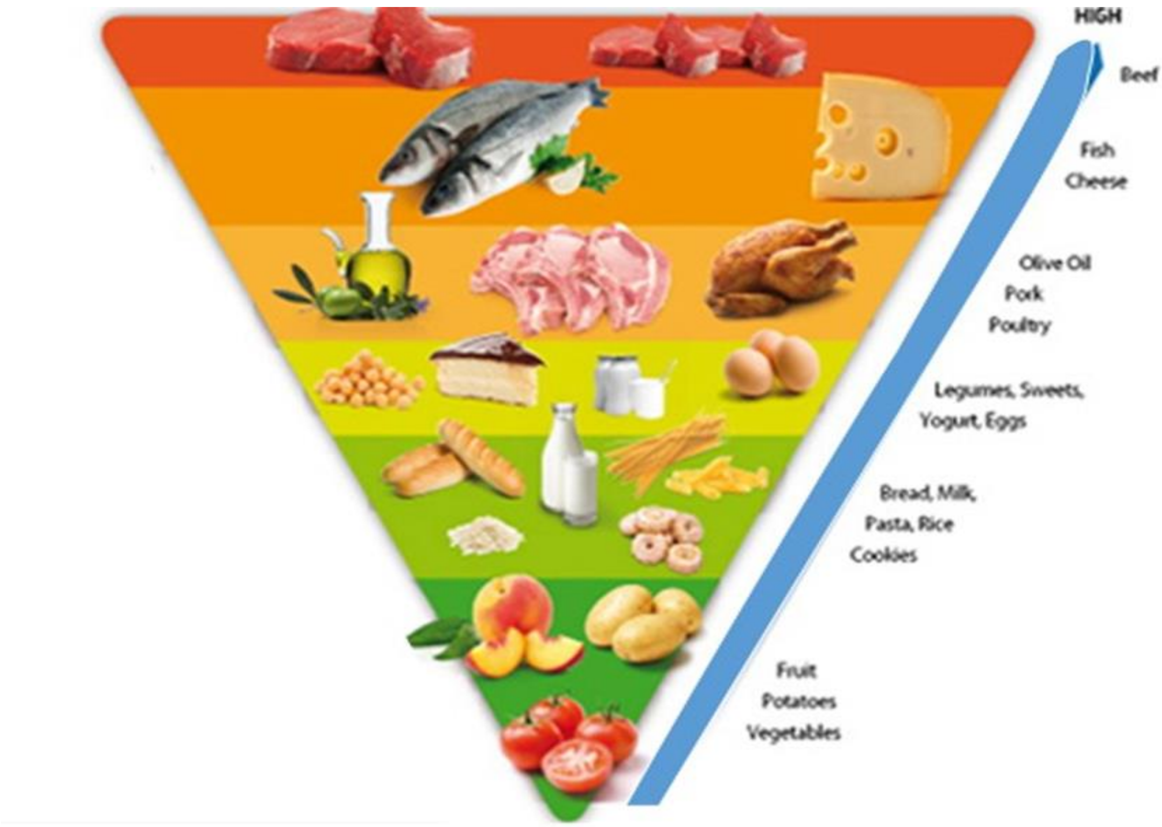

Figure 1-3 Inverted Food Pyramid depicting current consumption in Catalonia

Consumption of fruits and vegetables are below the recommended levels. Statistically, 58% of the sample did not meet recommendations for vegetable consumption and only 26% met those for fruit (Serra-Majem et al., 2007).

On the positive side, sixty-eight per cent met the recommendations for dairy products (28% with inadequate and 4% with excessive intakes) and 49% showed adequate intakes of olive oil.

Many studies have provided strong evidence on the beneficial effect of higher conformity to the Mediterranean food pyramid on risk of death from all causes, including cardiovascular diseases, and cancers (Sofi et al., 2008). This suggest the need to revisit the NAOS Strategy (Nutrition, Physical Activity and Prevention of Obesity) as health strategy since its goal is to reverse the prevalence of obesity by promoting healthy eating and the practice of physical activity (entrenched in the Mediterranean food pyramid).

Consequences of Poor Dietary Habits in Catalonia

Poor dietary habits among Catalan population has health and socio-economic consequences. According to data from the Health Survey of Catalonia (2012), almost half of the population over 18 years of age is overweight (57.7% of men and 40.1% of women). Specifically, 35.2% are overweight (which affects more men) and 13.8% are obese (similar in both sexes). The percentage of overweight and obese population is higher among the most disadvantaged social classes and those with less education, especially among the female population. Majority of studies have attributed the current prevalence of obesity to the sedentary life-style and unhealthy dietary habits (Román-Viñas et al., 2007).

Studies in developed countries have found a positive relationship between body mass index and days of hospitalization and medical bills among different age groups (Buescher et al., 2008; Hu et al., 2008; Korda et al., 2015). Kuriyama et al. (2002) found a U-shaped relationship between medical cost and BMI. The Spanish Society for the Study of Obesity (SEEDO) in 2004 estimated the direct and indirect cost attributable to obesity to be €2.5 billion per year, about 7% of the total health budget (SEC/2007/0706 final). Moreover, in Catalonia, Mora, Gil, & Sicras-Mainar (2015) found that being severely and moderately obese (overweight) increased medical costs by 26 % and 16%, respectively, compared to a normal-weight individual.

From the social context, individuals with obesity are usually discriminated. They are less likely to attend college (Crandall, 1994; Gortmaker et al., 1993), they are discriminated against in employment situations (Klesges et al., 1990; Rothblum et al., 1988), and they can have difficulty in finding and caring for a partner (Gortmaker et al., 1993; Molinari and Riva, 1995).

Discrimination against overweight and persons with obesity has result in higher body image dissatisfaction (Furnham et al., 2002; Volkow et al., 2013). However, some school of thought believes that weight stigmatization is a useful tool to motivate people with obesity to adopt healthier lifestyle behaviors (Hebl and Heatherton, 1998). In addition, individuals who perceive their bodies negatively with regard to culturally valued features usually suffer from low self-esteem, low satisfaction in life and feeling of inferiority and pose themselves at higher risk for depression, anxiety or eating disorders (Goswami et al., 2012).

Sustainable Consumption Policies

Adherence to the Mediterranean dietary pyramid provides the most effective and efficient way to simultaneously achieve both environmental and health goals. However, this requires the right health or environmental policy or both to influence food choices.

A wide range of policies have been introduced to alter food and beverage choices such as regulation of fast food outlets (Sturm & Cohen, 2009), or products at check-out (Horsley et al., 2014); labelling of food products (Fichera and Von Hinke, 2017); restriction of advertising of junk food (Chou et al., 2008); and “sin” taxes on specific goods such as alcohol or sugary soft drinks (O’Donoghue and Rabin, 2006).

Literature suggest that the dominant policy instruments in the food domain are mostly information-based and education oriented tools that focus on raising awareness and are often accompanied by voluntary strategies encouraging self-commitment, cooperation, and networking (Reisch et al., 2013). In addition, production strategies such as the classic command-and-control policy measures have proven to be politically difficult to achieve and practically inadequate to truly shape consumer choices (Scholl et al., 2010).

Just as tax deductions and exemptions can be used to encourage favoured behaviours, governments often impose taxes with the goal of discouraging a range of disfavoured behaviours, from increasing carbon emissions to smoking cigarettes to eating unhealthy foods (Olivola and Sussman, 2016). The introduction of taxes on sugar sweetened beverages (SSBs) across the world has been justified as a way to internalize externalities associated with the costs of unhealthy consumption, linked to obesity (Jacobson and Brownell, 2000).

The motivation for fiscal policy options as a strategy to tackle diet-related diseases is increasing with the failure of educational and informational interventions to achieve population-level changes in obesity (Elinder, 2005; Lang and Rayner, 2007). Market based policies such as taxes on certain food types (e.g., junk food) or food components (e.g., certain fats in Denmark) (Nicholls et al., 2011) have become attractive. With the goal of moving consumers away from unhealthy consumption of sugar sweetened beverages, the regional parliament of Catalonia approved a sugar-sweetened beverage tax on the 28th of March 2017 (locals a Catalunya, 2004). It followed WHO recommendations on the use of fiscal measures to tackle obesity and non-communicable diseases (World Health Organization, 2015). The tax came into place on the 1st of May 2017.

These examples suggest the importance of affecting consumer behaviour through fiscal policies. As a result, the first goal of this thesis is therefore to estimate the extent to which food choices can be influenced from both the environmental and health fiscal policy perspective. The conclusion was that consumers do not respond uniformly to taxes. However, despite their importance and ubiquity of consumers response to taxes, there has been relatively little research on the consumer psychology of taxes, and most of this work is quite recent (Epstein et al., 2010; Hardisty et al., 2010; Homonoff, 2012). This motivated the second goal which seeks to understand the psychological and behavioural factors that influence the development of a non-communicable disease such as obesity.

Incorporating Household Behaviour into Policy Formulation

The majority of economic analyses on the effect of taxes on behaviour change are silent about how much of this change results from purely economic factors relating to the cost of the tax versus from psychological reactions to its implementation. For instance, effects of taxes versus subsidies on food choice revealed that taxing unhealthy foods reduced the portion of fat purchased while subsidizing healthier foods had no effect on the nutrition quality of food purchased (Epstein et al., 2010). This brings to light the importance of psychological attitudes on consumer reaction to fiscal policies. Kahneman and Smith (2002) showed that consumers make lots of mistakes and errors when making food choices. Consumers are often unable to make the best choice for themselves, or sometimes they even do not know what is best for them. Moreover, consumers are often let down by too much information and choice; and suffer from risk aversion, loss aversion, myopia, impatience, and overconfidence.

In an effort to increase consumer response to taxes empirical studies should incorporate psychological attitudes of consumers into demand modelling. From the time inconsistency context, people may fail to consume goods with long-term benefits but high upfront costs, despite intentions to do so. This suggest that if consumers are time-inconsistent, taxes may benefit those who are price-sensitive by incentivising their self-control (Gruber and Kőszegi, 2004). It turns out that these taxes are less regressive if time inconsistent consumers are also those with low incomes. As sugar may be addictive (DiNicolantonio et al., 2018; Ventura and Mennella, 2011) and low-income individuals may be both more time-inconsistent and more affected by the tax. From the perspective of prospect theory (Kahneman and Tversky, 1979), consumers who are loss-averse would respond more to a tax (a loss) than an equivalent subsidy (a gain). It has therefore been concluded that for goods where the benefits are more distant relative to the costs – healthy foods, environmental health, education and so on, behavioural economics presents a clearer rationale for using taxes to promote their consumption than the standard economic model (Leicester et al., 2012).

The study of influence of psychological factors on how consumers make consumption choices about foods causing preventable non-communicable diseases like obesity, is a good precursor to understand consumer behaviour.

In the light of the above literature, this thesis seeks to answer the following research questions.

1.3 Research Questions

1) Can an environmental and/or health tax change consumer behaviour towards sustainable environmental and health goals without compromising on consumer welfare?

2) To what extent do behavioural factors predispose consumers to diet related diseases - obesity?

1.4 Objectives

The main goal of this thesis is twofold. The first goal is to examine the effectiveness of fiscal policies such as nutrient and environmental taxes on consumer behaviour under the assumption of rational and well informed consumers. The motivation for the first part of the study is that classical economic theory assumes that consumers make rational, self-interested and consistent choices about their consumption. Demand studies based on classical economic assumptions postulate that increases in prices = decreases in consumption which is consequently = reduction in emission/body weight. The first part of the thesis therefore seeks to address the following specific objectives:

i. To evaluate the effectiveness of a Pigovian tax based on EU environmental policy objectives on GHG emission reduction and diet quality.
ii. To evaluate the effectiveness of internalizing the social cost of obesity on macro- and micro- nutrient redistribution and consumer welfare.

The second goal is to analyse consumer behaviour from the context of rational addiction drawing from the body of literature in behavioural economics that suggest that consumers are influenced by bounded rationality, social norms, time inconsistency, uncertain outcomes – prospect theory. This shows that classical economics assumption oversimplifies the rather much more complex consumer behaviour, relegating the influence of psychological and individual heterogeneity on policies targeted consumption. As such, we go further to explain why fiscal policies do not usually achieve the intended desired results by policy makers. To this effect, this section analyses how psychological factors influence consumers' food choices through the development of obesity. Psychological factors such as aversion to losses/risk, time inconsistency, weight stigma etc. have been found to influence consumption choices reducing the effectiveness of fiscal policies. The second part of the thesis will therefore address the following specific objectives:

i. To estimate and evaluate how risk and time preferences of consumers influence their food choices and weight development.
ii. To develop a framework on how individual bio-psycho-eco-social factors interact to affect the development of obesity among consumers in Catalonia?

1.5 Structure, Contributions and Organization of Thesis

The thesis has been structured into six main chapters. The first chapter is the introduction of the thesis, this addresses the background on which the work was developed, the main goal and the contributions of the thesis. The next four chapters address each of the specific objectives outlined in the introduction. Each chapter assumes the form of a classic dissertation structure, divided into introduction, an empirical part, a discussion, and a conclusion at the end.

Despite the proliferation of studies on fiscal policy options for sustainable nutrient and climate goals in the policy arena: First, to the best of our knowledge, only a very few papers have been published dealing with the impact of taxation of unhealthy food consumption on CO_2 equivalent emissions reduction (Briggs et al., 2013; Edjabou & Smed, 2013; Garcia-Muros et al., 2017; Säll & Gren, 2015; Wirsenius et al., 2011). However, they are not exempted from criticisms. From a methodological point of view, these studies have relied on the AIDS model, ignoring the impact of unobserved household heterogeneity in welfare estimates. The second criticism is that with the exception of Edjabou & Smed (2013), who considered 23 food categories, past literature usually considered a reduced number of food products (meat, meat and dairy,…), ignoring potential substitution effects among the included food categories and those categories excluded from their analysis. In the case of Spain, only Garcia-Muros et al. (2017) have dealt with the distributional effects of carbon-based food taxes.

Chapter one differentiates itself from the aforementioned studies by addressing the following issues: 1) the demand model used is more flexible about the functional form of the Engle curves, and takes into account unobserved household heterogeneity in the welfare calculations; 2) the geographical scope is different, as the study is concentrated on a Spanish region - Catalonia; 3) tax scenarios are different with this study focusing on current EU medium- and long-term emission reduction objectives; and 4) this study focuses on revenue-neutral (compensated) tax scenarios.

Second, a few countries in Europe have implemented nutrient taxes with the goal of reversing the soaring prevalence rates of obesity. Among them are Hungary, in 2011 (Escobar et al., 2013); Finland, in 2011 and France, in 2012 (Berardi et al., 2016). Denmark has been the first country to introduce a tax on saturated fat (nutrient tax), which was implemented in October 2011 (Jensen et al., 2016; Smed, 2012) and abolished in 2012. Post-tax studies show the tax policy was effective in reducing fat consumption (Jensen et al., 2016; Smed, 2012).

Similarly, some studies have quantified the public cost of unhealthy (quantity/distribution) nutrient or food consumption on non-communicable disease like obesity (Finkelstein et al., 2003; Thorpe et al., 2004; Withrow and Alter, 2011). However, none of them has gone beyond this step by proposing a policy that could internalise these costs.

Chapter two builds on the limitations of previous studies by jointly considering the following four issues: 1) the estimation of the social cost of obesity from public health expenditure; 2) the internalisation of the social cost of obesity using a revenue-neutral (subsidize untaxed foods with revenues from taxed foods) policy simulation scenario to ensure that the potential effects of the tax are within the natural variation of the price change; 3) assessing the effectiveness of the tax reform on food and nutrient demand taking into account inter-relationships between all food categories and nutrients consumed (not only within a food group or category); and 4) the welfare impacts of the tax on different consumer segments.

Third, psychological factors such as risk and time preferences have major influence on how individuals make food choices (Anderson and Mellor, 2008; de Oliveira et al., 2016; Davis et al., 2010; Borghans and Golsteyn, 2006; Komlos et al., 2004; Smith et al., 2005). However, results from past studies have been inconclusive, methodologically and geographically limited. For instance, the study by Komlos et al. (2004) failed to control for covariates that may also be responsible for the rising pattern in obesity. Methodologically, most studies are based on the Iowa gambling task (Bechara, 2007), Balloon Analogue Risk Task (BART) (Lejuez et al., 2002), self-reported risk parameters (Barratt, 1985). In addition, some studies rely on self-reported BMIs which makes their results refutable.

Chapter three relies on household and experimental data to improve on the limitations cited in the preceding paragraph. This study differentiates itself from previous research by introducing the following novelties: 1) derives risk preference parameters (risk, loss aversion, and probability weighting) and time preference parameters (discount rate, present bias and hyperbolicity) using the double Multiple Price List approach of Tanaka et al. (2010); 2) this study uses measured weights and heights to estimate the BMI of subjects instead of relying on self-reported measures; and 3) use robust least squares and time discounting models to establish the correlation between body mass index and the parameters from (1); and 4) control for a variety of individual covariates, including marital status, education, age and income that have been shown to be drivers of obesity.

Finally, the causes of obesity are multifactorial (Cutler et al., 2003). As such, past studies have carried incomplete studies or reviews that seek to establish the relationship between obesity and social/environmental (Cohen-Cole and Fletcher, 2008; Klaczynski et al., 2004), psychological (Leon and Roth, 1977), economic (Wright and Aronne, 2012) and demographic factors (Wright and Aronne, 2012). However, none of these studies considered all these multi-factors at a goal. Chapter four of this thesis therefore improves past research by 1) considering the interactions among individual psychological attitudes i.e. risk/time preferences; social behaviours i.e. beliefs about obese persons (BAOP) or attitudes towards people with obesity (ATOP); physiological views i.e. body image dissatisfaction/misperception; socio-economic characteristics and body mass index. 2) providing empirical estimates for the possible direction and strength of association that exist among the variables and obesity. 3) relying on household and experimental data instead published works. 4) provide context specific estimates i.e. this is the first study to carry out empirical review on the possible factors driving adult obesity in Catalonia.

The final chapter of this thesis presents the general summary and implications of the entire study. To consolidate the specific objectives, this chapter synthesizes the overall findings, which follows the research implications for consumers and policy makers. Several future research directions are suggested and limitations addressed.

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CHAPTER 2

Effectiveness of a Carbon Tax to promote a climate-friendly food consumption

2.1 Introduction

Our current dietary habits are a major contributor to climate change because the "seed-to-table" food chain produces an immense amount of greenhouse gases (GHGs) (Castellón et al., 2015). For instance, in Spain, the agricultural sector contributes 14% of the country's total greenhouse gas (GHG) emissions (Bourne et al., 2012). Hedenus et al. (2014) showed that emission reduction in the agro-food sector can be achieved by: 1) productivity improvements; 2) technological changes (supply-side measures); and 3) changes in consumption behaviour (demand-side measures). Supply side measures such as command-and-control regulations, cap-and-trade systems or Pigovian (corrective) taxes, have been applied extensively in the European Union (Máca et al., 2012). However, the use of command–and-control measures has been found to be economically inefficient and does not lead to optimal production, when compared to cap-and-trade measures or Pigovian taxes (Burchell and Lightfoot, 2001)

Pigou (1928) proposed that governments should influence the behaviour of economic agents causing negative (positive) externalities through taxes (subsidies) (Endres, 2010). Influencing suppliers through taxes is a delicate issue because of "carbon leakage[1]" (Wirsenius et al., 2011) and high monitoring costs (Schmutzler and Goulder, 1997). From the demand side, the relevance of a Pigovian tax on unhealthy/high-carbon-footprint foods is justified under the assumption that the food industry is close to perfect competition[2]. Under such an assumption, the incidence of a Pigovian tax is irrelevant, whether applied to the supply side or the demand end. For this reason, several studies have shown that imposing Pigovian taxes on food demand rather than on food supply constitutes a cost-efficient emission reduction strategy (Edjabou and Smed, 2013). Consumption taxes are also more attractive from the climate perspective (Mytton et al., 2012). Säll & Gren (2015) and Wirsenius et al., (2011) argued that the tax should be imposed on consumption and not directly on the emissions. This preserves the competitiveness

[1] The European Commission defines carbon leakage as the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints.

[2] According to Edjabou and Smed (2013) food markets are characterised by near-perfect competition, which implicitly assumes that the tax incidence between food producer and consumer does not depend on whether it is the producer or the consumer who is taxed since, on a long term basis, the tax in both cases is likely to end at the consumer. We acknowledge that a deviation from this assumption will have serious consequences on our results. As such the result should be interpreted with caution.

of domestic products in relation to imported ones and it efficiently allows consumers to adjust to the taxes according to their efficient level of consumption (internalizing the externality).

Influencing consumer behaviour through food taxes is not new. Several countries have introduced taxes on food consumption as a way of internalizing negative externalities associated with the intake of unhealthy and environmentally unfriendly food products (Springmann et al., 2016). In an attempt to improve health, in 2010 Denmark increased the existing taxes on some sugar products, soft drinks and cigarettes and introduced a tax on saturated fat in October 2011 (Smed, 2012). In 2011, Hungary also passed an excise tax on foods and beverages high in caffeine, fat, and sugar, which included both soft drinks and energy drinks (Escobar et al., 2013) with the objective of internalizing the cost of obesity related diseases. Similarly, Finland, in 2011, introduced a tax on sweets, ice-creams and soft drinks. Following Hungry, Denmark and Finland, France introduced the 'soda tax' in January 2012 with the aim of reducing unhealthy consumption of sugar or sweeteners (Berardi et al., 2016). The Mexican government in September 2013 imposed excise taxes on sugar sweetened beverages and a sales tax on several highly energy dense foods (Colchero et al., 2016) to reduce the prevalence of obesity and related diseases. Berkeley (California, USA) has taxed sugar-sweetened beverages (Cornelsen and Carreido, 2015).

In a meta-analysis, Escobar et al. (2013) showed that increasing the prices of sugar-sweetened beverages (SSBs) led to a reduction in the prevalence of obesity and overweight. Jensen & Smed (2013) found that the consumption of fats in Denmark dropped by 10% following the fat tax in 2011 while a later study by Smed et al. (2016) found that the consumption of saturated fat decreased by about 4-5% on average. Escobar et al. (2013), Jensen & Smed (2013) and Smed et al. (2016) provide evidence that seems to suggest that taxes on food can change consumption behaviours and internalize the associated negative externalities.

Based on the evidence provided, the objective of this paper is to evaluate the potential effects of imposing a "Pigovian" CO_2 equivalent tax on food products in Catalonia (North-East Spain). From food demand elasticities, we show that levying a CO_2 equivalent tax has three effects: 1) reduction in the consumption of high carbon footprint foods with consequences on nutrient intake and the quality of diet; 2) a reduction in GHG emissions; and 3) welfare effects.

Despite the increasing importance of this topic in the policy arena, as well as among researchers, to the best of our knowledge, only a very few papers have been published dealing with the impact of taxation of unhealthy food consumption on CO_2 equivalent emissions reduction (Briggs et al., 2013; Edjabou & Smed, 2013; Garcia-Muros et al., 2017; Säll & Gren, 2015; Wirsenius et al., 2011). Wirsenius et al. (2011) found that EU-27 could reduce approximately 32 million tons of CO_2-eq if they imposed a GHG weighted tax on animal food products corresponding to 60 Euro per ton CO2-eq. Similarly, Edjabou & Smed (2013) internalizing the social costs of greenhouse gas emissions by imposing CO_2-eq consumption taxes on 23 different foods found that emission would decline by 2.3–8.8% and 10.4–19.4% in the least and most efficient scenarios, respectively. Säll & Gren, (2015) extended the work of Wirsenius et al., (2011) and found that imposing a tax on all meat and dairy products decreased emissions of GHG, nitrogen, ammonia and phosphorus from the livestock sector by up to 12%. Garcia-Muros et al., (2017) evaluated the implications of levying consumption taxes on food products in Spain based on their carbon footprint. Using demand elasticities computed from the LAIDS model showed that a CO_2-eq tax policy could reduce emissions and, at the same time, help to change consumption patterns towards healthier diets.

The above papers provide sound empirical evidence that taxes on food products based on their carbon footprints can lead to decreased CO_2-eq emission and improve dietary compositions. However, they are not exempted of criticisms. From a methodological point of view, past studies have relied on the AIDS model, ignoring the impact of unobserved household heterogeneity in welfare estimates. The second criticism is that with the exception of Edjabou & Smed (2013), who considered 23 food categories, past literature usually considered a reduced number of food products (meat, meat and dairy,…), ignoring potential substitution effects among the included food categories and those categories excluded from their analysis. In the case of Spain, only Garcia-Muros et al. (2017) have dealt with the distributional effects of carbon-based food taxes. However, our study differentiates from the later in several issues: 1) as mentioned, the demand model used in this study is more flexible about the functional form of the Engle curves and takes into account unobserved household heterogeneity in the welfare calculations; 2) the geographical scope is different, as our study is concentrated on a Spanish region - Catalonia; 3) tax scenarios are different with this study focusing on current EU medium- and long-term emission reduction objectives; and 4) this study focuses on revenue-neutral (compensated) scenarios.

The remainder of the article is structured as follows. Sections 2 and 3 describe the data and the methodological framework used in this study. Section 4 shows and discusses main results. The paper ends with some concluding remarks and limitations.

2.2 Methodological Framework

Data

This study uses microdata: home scan panel data from a sample of 1146 households[3] in Catalonia (Northeast Spain) collated by Kantar Worldpanel. From the total of 1146 households, only those who had remained in the sample for at least 45 weeks were considered. Purchased quantities and expenditures for each single food product reference have been aggregated to the annual level for each household. The data set contains all day-to-day records of food purchases of Catalonian households in 2012. Each record in the Kantar data set contains detailed product information down to the Universal Product Code (UPC) level, including the store in which the household makes the purchases, product weight, price, unit of measurement, product characteristics (such as container type, brand, and flavor) and some household socio-demographic characteristics such as nationality, age, social class, presence of kids, number of pets, size of pets etc. Household´s also recorded, in a book, non-UPC items as fresh fruits or vegetables, and in-store packaged breads and meats.

Using established Spanish Ministry of Agriculture nutrition-based guidelines, food products have been aggregated into 16 food categories[4] (alcoholic drinks are not included, while non-alcoholic drinks are included in the residual category for the purpose of this paper) : 1) Grains and grain-based products, 2) Vegetables and vegetable products, 3) Starchy roots, tubers, legumes, nuts and oilseeds, 4) Fruit, fruit products and fruit and vegetable juices, 5) Beef, veal and lamb; 6) Pork, 7) Poultry, eggs, other fresh meat; 8) Processed and other cooked meats, 9) Fish and other seafood, 10) Milk, dairy products and milk product imitates, 11) Cheese, 12) Sugar and confectionary and prepared desserts, 13) Plant based fats, 14) Composite dishes (animal and vegetable composite dishes), 15 Snacks and other foods, 16) Residual category.

To standardize the products, all quantities were converted into kilograms and prices into euros. Similar to Zhen et al., (2014) the lowest level of aggregating the price data was the brand level. The brands were identified as belonging to subgroups and then to one of the 16 commodity groups.

[3] The sample is designed to represent the sociodemographic characteristics of households in Catalonia. Each household is assigned a weight in order to estimate total consumption for Catalonia. In this study, working with the raw data, only rural households are slightly underrepresented.

[4] The percentage of households with zero expenditures in the 16 food categories is shown in Table 2-1.

To circumvent the problem of unit values encountered in cross-sectional data[5], we followed Diewert (1998) to construct Fisher price indices[6] for the 16 food groups in our data using brands as the lowest level of aggregation. The Fisher price index, which is the geometric mean of the Laspeyeres and Paache indices, represents the deviation of the price paid by a household relative to the average household. For instance, to construct the price index for the residual category, we followed the following procedure:

1) Determination of the price per unit for a relatively homogeneous in-quality product. In this case, the unit value for the aggregate product *g* within food category *j* for the *h*-th household was calculated as:

$$UV_{gj}^{h} = \frac{\sum_{m=1}^{M} p_{mgj}^{h} * q_{mgj}^{h}}{\sum_{m=1}^{M} q_{mgj}^{h}} \qquad (1)$$

where p_{mgj}^{h} is the *h*-th household price of the *m* brand in aggregate product *g* within the food category *j*, and $q_{mgj}^{h}$is the *h*-th household quantity purchased of the *m* brand in aggregate product *g* within the food category *j*.

2) Construction of the Fisher price indices using the UV_{gj}^{h} values obtained in the first stage. The Fisher price index for the *h*-th household food category *j* is calculated as:

$$P_{Fj}^{h} = \sqrt{P_{Pj}^{h} * P_{Lj}^{h}} \qquad (2)$$

where P_{Lj}^{h} and P_{Pj}^{h} represent *h*-th household Laspeyres and Paasche price indices for food category *j*, respectively.

$$P_{Pj}^{h} = \frac{\sum UV_{gj}^{h} * q_{gj}^{h}}{\sum UV_{gj} * q_{gj}^{h}} \qquad (3)$$

and

[5] We have aggregated our panel to a cross-sectional data for the following reasons: first, seasonality effects have to be taken into account. Some seasonal effects are easy to handle but others are not so easy. In case we had had three or four years, this issue would not have been a problem; second, and more relevant, the number of zero purchases increased significantly adding an additional econometric issue. We tried a double hurdle model for that but the joint estimation of a 16-equation multivariate probit and the EASI model was not econometrically feasible due to convergence problems.

[6] Secondly, by implementing the Fisher price index we able to reduce the level of heterogeneity bias in the aggregation of our data into a cross-sectional data and abstract out quality variation due to product heterogeneity (Silver and Heravi, 2006; Zhen et al., 2014)

$$P_{Lj}^{h} = \frac{\sum UV_{gj}^{h} * q_{gj}}{\sum UV_{gj} * q_{gj}} \quad (4)$$

where UV_{gj}^{h} is the unit value for aggregate product g within food category j for the h-th household as defined previously, UV_{gj} is the unit value for aggregate product g within food category j for the average household and q_{gj} is the average quantity purchased for aggregate product g within food category j for the average household.

Table 2-1 shows the main household characteristics of the sample used in this paper. In the upper part, data on food expenditure[7] shares of the sixteen food groups are provided. As can be observed, the average household spends 21% of the food expenditure on fruits and fruit products, and milk and milk product imitates, respectively. The next significant food category for the average household is vegetables and vegetable products, followed by poultry, eggs and other fresh meat. The food category that attracted the lowest expenditure share is snacks and other foods. Among the socio-demographic characteristics, for the purposes of this study and taking into account the information available in the dataset about households' characteristics, we have included age, presence of kids and the social class, as in Ricciuto et al., (2006). Table 2-1 shows that, 21%, 20% and 59% percent of the households belong to the high, low and middle social class category, respectively. Households with kids were in the minority representing 35.6% of the sample.

Estimating Food Price Elasticities

Food price elasticities have been calculated by estimating an approximate EASI demand model (Lewbel and Pendakur, 2009), which incorporates household characteristics. The EASI demand model has several advantages over the traditional Almost Ideal Demand System (AIDS), as it derives the Implicit Marshallian demand function which combines desirable properties of both the Hicksian and Marshallian demand functions. Moreover, the error terms can be interpreted as unobserved preference heterogeneity among individuals and Engle curves can adopt any shape over real expenditures. Finally, similar to the AIDS model, we can estimate a linear approximation which generates results similar to the full model.

[7] Food expenditure used in our data refers to food-at-home expenditure. Kantar Worldpanel did not provide data on food-away-from-home neither on household income. Henceforth, we have assumed weak separability of food-at-home expenditure on total expenditure. Instead of income, the dataset provides information about the social class the household belongs. Social class is defined by the following four groups of household characteristics: 1) Occupation of all household members; 2) General characteristics of the living place (size, location, ownership,…); 3) Household equipment; and 4) Number and characteristics of owned vehicles.

Table 2-1 Household characteristic (%)

	Variable	Non-Consuming Households (%)	Mean	Std. Dev
Food-at-home Expenditure Shares	Grains and grain-based products	0.00	0.045	0.03
	Vegetables and vegetable products	0.00	0.131	0.07
	Starchy roots, tubers, legumes, nuts and oilseeds	0.50	0.016	0.01
	Fruit and fruit products	0.00	0.207	0.09
	Beef, veal and lamb	3.10	0.021	0.02
	Pork	1.00	0.020	0.01
	Poultry, eggs, other fresh meat	0.30	0.067	0.04
	Processed meat products	0.20	0.037	0.02
	Fish and seafood	0.10	0.046	0.03
	Milk and dairy products	0.00	0.210	0.10
	Cheese	0.30	0.024	0.01
	Sugar and confectionary and prepared desserts	0.00	0.055	0.03
	Plant based fats	3.00	0.027	0.02
	Composite dishes	1.10	0.063	0.05
	Snacks and other foods	2.70	0.008	0.01
	Residual category	0.30	0.025	0.02
Socio-demographics	High Social Class		0.213	0.41
	Low Social Class		0.197	0.40
	Lower Middle Social Class		0.238	0.43
	Middle Social Class		0.352	0.48
	0-34 years		0.090	0.29
	35-49 years		0.422	0.49
	50-64 years		0.332	0.47
	60+ years		0.155	0.36
	Presence of Kids 0-5 years		0.158	0.36
	Presence of Kids 5+ years		0.198	0.40
	No Kids		0.644	0.48

The approximate EASI demand equation expresses the budget shares, $w_{hi},$ as a function of food prices P, real household food expenditure $\tilde{y}$, and K socio-demographic characteristics z:

$$w_{hi} = \sum_{r=1}^{5} v_{ir}\tilde{y}_h^r + \sum_{j=1}^{N} a_{ij} lnP_{hj} + \sum_{j=1}^{N} b_{ij} lnP_{hj}\tilde{y}_h + \sum_{k=1}^{K} c_{ik} z_{hk} + \sum_{k=1}^{K} d_{ik} z_{hk}\tilde{y}_h + u_{hi}$$

where w_{hi} is the budget share of the i-*th* category for the h-*th* household; N is the number of food categories; $\tilde{y}_h$ is the real food expenditure for h-th household ($\tilde{y}_h = lnx_h - \sum_j^N \bar{w}_h$); *5* is the highest order of polynomial in $\tilde{y}_h$ to be determined empirically; P_{hj} is the price index of the *j*-th food category paid by the *h*-th household; *K* is the number of exogenous demand shifters; z_{hk} is the *k*-th demand shifter for the *h*-th household, with z_{h1} being a constant; a_{ij}, b_{ij}, c_{ik}, d_{ik} *and* v_{ir} are parameters to estimate; and $u_{hi}$is error term, which accounts for unobserved preference heterogeneity. For the model to be consistent with theory, the budget share equations w_{hi} are required to satisfy the properties of adding-up, linear homogeneity and Slutsky symmetry.

The EASI demand system was estimated using 3-Stage least Squares to account for endogeneity. There are two sources of endogeneity. First, the presence of budget shares in the stone index makes this index to be endogenous[8]. Second, the real food expenditure ($\tilde{y}_h$) is a function of the endogenous food group expenditure (x_h). In our conditional food-at-home demand model, we have controlled for this form of endogeneity by using social class as a proxy for income to instrument for food groups expenditure (x_h)[9].

By taking the derivatives of (5) with respect to log prices and expenditure, we get the Hicksian demand semi-elasticities, which were converted into price elasticities following Castellón et al. (2015) and expenditure elasticities following Zhen et al. (2014).

- Hicksian price elasticities for *i*-th good with respect to the price of the *j*-th food product was calculated as:

$$\boldsymbol{H_{ij}} = \frac{(\boldsymbol{a_{ij}} + \boldsymbol{b_{ij}}\tilde{\boldsymbol{y}})}{\boldsymbol{w_i}} + \boldsymbol{w_j} - \boldsymbol{\delta_{ij}} \quad (6)$$

[8] Lewbel & Pendakur (2009) and Zhen et al., (2014) have shown that this source of endogeneity in demand models is numerically unimportant.
[9] Another way of dealing with this form of endogeneity is to estimate an incomplete food-at-home demand model as in Zhen et al. (2014) and ignore the need to use instruments. However, this strategy needs information about household income which is not available in our dataset.

where δ_{ij} =1 if i =j, and 0 otherwise.

- The N x 1 vector of food expenditure elasticities, *FE* was calculated as:

$$\boldsymbol{FE} = (\boldsymbol{diag}(\boldsymbol{W}))^{-1}[(\boldsymbol{I_j} + \boldsymbol{XP'})^{-1}\boldsymbol{X}] + \boldsymbol{1_j} \tag{7}$$

where $\boldsymbol{W}$ is the $N \times 1$ vector of observed budget shares, $\boldsymbol{X}$ is a $N \times 1$ vector whose *i-th* element equals $\sum_{r=1}^{5} rv_{ir}y^{r-1} + d_{ik}z + b_{ij}p$, $\boldsymbol{P}$ is the $N \times 1$ vector of log prices, and 1_j is a N×1 vector of ones.

- The Marshallian price elasticity, $\boldsymbol{\varepsilon_{ij}}$, were recovered from the Slutsky equation using:

$$\boldsymbol{\varepsilon_{ij}} = \boldsymbol{H_{ij}} - \boldsymbol{w_j} * \boldsymbol{fe_i} \tag{8}$$

Where $\boldsymbol{fe_i}$ is the *i*-th element of ***FE.***

Measuring The Impact Of CO_2 Equivalent (CO_2-Eq) Tax on Food Demand

To measure the impact of CO_2-eq tax on food demand, we needed data on CO_2 emissions per kilogram of food products. Although several studies have provided some figures, there is no single study that covers all the food categories considered in this study in Spain (Macdiamid et al., 2012). For complete and comprehensive estimates, CO_2 equivalent emissions for major food products consumed in the EU were taken from Hartikainen & Pulkkinen (2016)[10]. Their estimates were based on the following assumptions: 1) they are restricted to the food chain (from primary production to final consumption, encompassing processing, packaging [including recycling of packaging material], storing and cooking); 2) transport activities (including consumers' displacement to retail outlets) are not included; 3) GHG emissions due to food waste were not accounted for; and 4) direct land-use changes were not considered due to lack of data. The work also considers changes in the weight of food products because of evaporation, addition of water for cooking and exclusion of inedible parts[11]. Despite the limitation to using this data due to differences in food production systems in Spain and other EU countries, we consider that the data set will serve the purposes of this study because it uses a common framework to estimate GHG emissions for a large list of food products.

[10] Although this dataset contains information for a large number of food products, we could not find information for 9 out of the 112 products considered in this study (minced beef; all other beef and veal; all other lamb; pork joints; pork chops; all other pork; chicken and turkey, cooked; turkey, uncooked - whole turkey or turkey pieces; bacon and ham, cooked). In the case of missing information, we took the data from Bonnet et al. (2018).

[11] Hartikainen & Pulkkinen (2016) estimates are based on ready-to-eat foods. They used the conversion factor proposed by McCance and Widdowson (2015). However, in their dataset, transport emissions are not considered. For the purpose of our estimation, we assume that our food products are all ready-to-eat (ignoring the impact of exclusion or inclusion of inedible parts).

To determine the average CO_2-eq emissions from each food category, we multiplied the average daily consumption (kg) of each food group by their corresponding average CO_2-eq emissions to obtain the average CO_2-eq emissions per kg of food category per day for the 16 food groups considered in this study (see Table 2-2). The impact of imposing a carbon/green tax on demand for food has been analysed, taking into account the price/ton of CO_2 equivalent emissions for each of the 16 food categories. Previous studies have used a wide range of values ranging from 0 Euro up to 365 Euro (Stern, 2007). To cite only two examples, Edjabou & Smed (2013) based on the Tol (2012) and (Stern, 2007) estimates, assumed a carbon social cost of 30 Euro per ton and a CO_2 equivalent of 100 Euro per ton, respectively. (Irz et al., 2015) assumed a value of 32 Euro, based on the meta-analyses carried out by Tol (2012).

Table 2-2 Average kg CO2 equivalent emissions per kg for each food category

Food Category	*kg CO2-eq/kg food/day*	*Standard Deviation*
Grains and grain-based products	1.10	0.30
Vegetables and vegetable products	1.20	0.70
Starchy roots, tubers, legumes, nuts and oilseeds	0.40	0.50
Fruit and fruit products	0.90	0.70
Beef, veal and lamb	18.90	11.70
Pork	5.80	0.20
Poultry, eggs, other fresh meat	5.90	1.70
Processed meat products	5.40	0.40
Fish and seafood	5.30	2.30
Milk and dairy products	1.50	0.10
Cheese	8.20	0.05
Sugar and confectionary and prepared desserts	1.20	0.50
Plant based fats	2.60	1.00
Composite dishes	12.50	8.60
Snacks and other foods	1.90	0.20
Residual category	1.30	0.30

Source: Own elaboration from Hartikainen & Pulkkinen (2016)

Simulation scenarios

This study aims to simulate two tax scenarios (compensated and uncompensated), following Edjabou & Smed (2013). In the uncompensated (U) scenario, taxes were imposed on all food groups proportional to their carbon footprint. In the compensated (C) scenario, the taxes were imposed, as in Säll & Gren (2015), only on those food categories that generate higher GHG-emissions: all meats, milk and dairy products, cheese and composite dishes (see Table 2-2). Additionally, tax revenues generated from the above mentioned taxed foods were used to subsidize the rest of the foods that generate comparatively lower CO_2-eq emissions per kg.

Under both scenarios (U and C), this study considers two different policy goals taking into account the EU's medium- and long-term carbon emission reduction objectives. The EU proposes a social cost of CO_2/t equivalent emission of 56 EUR (scenario 1) and 200 EUR (scenario 2) to reduce total greenhouse gas emissions by 20% and 60% by 2020 and 2050, respectively, across the EU (Quinet, 2009). Thus, in total, this study considers four tax scenarios U1, U2, C1 and C2 (Table 2-3)

In scenarios U1 and U2 (uncompensated case under the two policy goals) and following Baumol & Oates (1975), the taxes imposed on each food category was calculated as follows:

$$\boldsymbol{t_i = \rho_i * \varphi} \qquad (9)$$

where t_i is the tax imposed on the i-th food category, ρ_i is the used average CO_2 equivalent for the i-th food group and φ is the social cost of releasing 1 kg of GHG measured in CO_2 equivalents in scenarios 1 or 2.

In scenarios C1 and C2 (compensated case), we have followed the seminal paper by Edjabou & Smed (2013) to create revenue-neutral policy scenarios. Under both cases, the new price, $\boldsymbol{p_{i1}}$ for the subsidized i-th food category that was not taxed was calculated as:

$$\boldsymbol{p_{i1}} = p_{i0} - \emptyset * p_{i0} \qquad (10)$$

where $\emptyset$ is a consistently positive factor and p_{i0} is the price of the i-th food category with the CO_2-eq tax from scenarios U1 or U2 (Table 2-3). The value of $\emptyset$ is determined as the value where the total tax revenue after the price change equals the tax revenue before the price change. Based on the above method, the subsidies ($\emptyset$) generated for scenarios C1 and C2 are: $\emptyset_{C1}$= 8% and $\emptyset_{C2}$=27%, respectively.

Table 2-3 Description of tax scenarios (taxed products and social cost emissions associated to each scenario)

	Uncompensated Scenario		Compensated Scenario	
Scenario	U1	U2	C1	C2
Food categories				
Grains and grain-based products	X	X		
Vegetables and vegetable products	X	X		
Starchy roots, tubers, legumes, nuts and oilseeds	X	X		
Fruit, fruit products and fruit and vegetable juices	X	X		
Beef, veal and lamb	X	X	X	X
Pork	X	X	X	X
Poultry, eggs, other fresh meat	X	X	X	X
Processed and other cooked meats	X	X	X	X
Fish and other seafood	X	X		
Milk, dairy products and milk product imitates	X	X	X	X
Cheese	X	X	X	X
Sugar and confectionary and prepared desserts	X	X		
Plant based fats	X	X		
Composite dishes	X	X	X	X
Snacks and other foods	X	X		
Residual category	X	X		
Social cost of emission				
EU 2020 (56 Euro)	X		X	
EU 2050 (200 Euro)		X		X

Table 2-4 summarizes the price changes under the different tax scenarios considered in this paper. As can be observed, in the two uncompensated scenarios, but mainly in scenario U2, price changes range from about 2% (starchy roots, legumes and pulse category) to 44% (beef, veal and lamb category) and 55% (composite dishes). Even if the policy goal is aimed to be achieved exclusively by a tax policy, it is unreliable assuming that policy makers would tax food products generating prices outside their natural variation. Moreover, taxing all categories would not be plausible, as the potential reduction in the consumption of all food products could have negative consequences on households that are poorer as well as on the overall population's quality of diet (i.e. the reduction in the consumption of fruits and vegetables). For this reason, for the rest of this study, we will concentrate all the analyses in the compensated or revenue neutral scenarios. Under such scenarios, all untaxed food categories are subsidized equally while taxed foods remained as in the uncompensated case.

Table 2-4 Price changes under alternative tax scenarios (%)

% changes relative to baseline	UNCOMPENSATED SCENARIOS		COMPENSATED (REVENUE-NEUTRAL) SCENARIOS	
Food Groups	U1	U2	C1	C2
Grains and grain-based products	2%	8%	-8%	-27%
Vegetables and vegetable products	4%	13%	-8%	-27%
Starchy roots, tubers, legumes, nuts and oilseeds	0%	2%	-8%	-27%
Fruit, fruit products and fruit and vegetable juices	4%	13%	-8%	-27%
Beef, veal and lamb	12%	44%	12%	44%
Pork	4%	14%	4%	14%
Poultry, eggs, other fresh meat	9%	33%	9%	33%
Processed and other cooked meats	4%	13%	4%	13%
Fish and other seafood	3%	12%	-8%	-27%
Milk, dairy products and milk product imitates	6%	22%	6%	22%
Cheese	6%	22%	6%	27%
Sugar and confectionary and prepared desserts	1%	5%	-8%	-27%
Plant based fats	6%	20%	-8%	-27%
Composite dishes (animal and vegetable composite dishes)	15%	55%	5%	55%
Snacks and other foods	2%	6%	-8%	-237%
Residual category	2%	6%	-8%	-27%

*See Table 2-3 for the description of each scenario (subsidies are negative; taxes are positives).

The percentage reduction in the quantities consumed after imposing the taxes were calculated taking the own- and cross- price elasticities into account:

$$\frac{\Delta Q_i}{Q_i} = \sum_j^N \varepsilon_{ij} * \frac{\Delta p_i}{p_i} \quad (11)$$

where $\frac{\Delta P_i}{P_i}$ and $\frac{\Delta Q_i}{Q_i}$ represent the percentage change in prices and quantities of the i-th food group after the tax, respectively (Säll and Gren, 2015).

Finally, the post-tax change in CO_2 equivalent emission for the h-th household $\Delta \boldsymbol{Em_h}$ was obtained by multiplying the change in consumption for the i-th food category, $\Delta \boldsymbol{Q_i}$ by the CO_2 equivalent emission per kg of the i-th food category.

$$\Delta \boldsymbol{Em_h} = \sum_j^N \rho_{i_j} * \Delta \boldsymbol{Q_i} \quad (12)$$

where ρ_{ij} is the used average CO_2 equivalent for the i-th food group and $\Delta \boldsymbol{Q_i}$ is the change in quantity taking into account own- and cross- price elasticities.

Estimating The Impact of CO_2-Eq Tax on Household's Welfare

In order to calculate the impact of the aforementioned taxes on a household's welfare, being consistent with previous literature, we have assumed that the food supply is perfectly inelastic and is not influenced by the CO_2-eq tax. This implicitly assumes that the tax burden between Catalonian food producers and consumers does not depend on whether it is the producer or the consumer who is taxed, since in the long term, the tax is likely to end on the consumer[12]. Under this assumption, welfare estimates are calculated through the so-called log of living cost index of Lewbel & Pendakur (2009) which takes into account both first-order and second-order effects. The first order-effect assesses the distributional impact of the tax imposition on each food category as the product of its corresponding budget share by the price change in that food category, while the second order-effect considers how consumers react to price changes:

$$\boldsymbol{C}(\boldsymbol{p_1}, \boldsymbol{u}, \boldsymbol{z}, \boldsymbol{\varepsilon}) - \boldsymbol{C}(\boldsymbol{p_0}, \boldsymbol{u}, \boldsymbol{z}, \boldsymbol{\varepsilon}) = (\boldsymbol{p_{i1}} - \boldsymbol{p_{i0}})'\boldsymbol{w_0} + \boldsymbol{0.5}(\boldsymbol{p_{i1}} - \boldsymbol{p_{i0}})'\left(\sum_j^N \boldsymbol{a_{ij}} + \boldsymbol{b_{ij}}\tilde{\boldsymbol{y}}\right)(\boldsymbol{p_{i1}} - \boldsymbol{p_{i0}}) \quad (14)$$

The term $(\boldsymbol{p_1} - \boldsymbol{p_0})'\boldsymbol{w_0}$ in (14) is the Stone index for the price change while $\boldsymbol{0.5}(\boldsymbol{p_{i1}} - \boldsymbol{p_{i0}})'\left(\sum_j^N \boldsymbol{a_{ij}} + \boldsymbol{b_{ij}}\tilde{\boldsymbol{y}}\right)(\boldsymbol{p_{i1}} - \boldsymbol{p_{i0}})$ models substitution effects resulting from price changes.

[12] We acknowledge that a deviation from this assumption could have consequences on our results. First, the tax burden will be shared by both consumers and producers, affecting the competitiveness of domestic firms. Second, the magnitude of the impact on consumption (reduction in quantity and emissions) could likely to be lower. However, it is also true that in the short run producers cannot modify their supply taking into account the existence of fix costs.

To estimate the welfare effects for the *k*-th social demographic group, we subsampled the data based on the *k*-th demographic group to estimate the average prices and average budget shares, which were introduced into equation (14).

2.3 Results and Discussion

Price and Food Expenditure Elasticities

The EASI demand model in (5) has been estimated imposing adding-up, homogeneity and symmetry[13]. Several Wald tests have been carried out to check for model adequacy. In relation to the functional form of the Engle curve, we followed a sequential procedure. We considered first a 5-degree polynomial and test for the significance of the fifth parameter. As the p-value was 0.75, we consider a fourth-degree polynomial as test for the significance of the fourth parameter. Its p-value was 0.50. We repeated the process with a cubic functional form and here we obtained a 0.005 p-value, indicating that a cubic functional form was appropriate in our case. Finally, we tested for the joint significance of the interaction parameters between socio-demographic variables and prices and real food expenditure, respectively. Results indicated that parameters associated to interactions with prices were not jointly statistically significant (p-value 0.78), while were significant in the case of real expenditure (p-value 0.003).

Table 2-5 shows the calculated food expenditure as well as Marshallian own- and cross-price elasticities[14]. Food expenditure elasticity estimates are statistically significant at the 1% level and positive. Three food groups out of the 16 are food expenditure elastic, including vegetables and vegetable products, fruit and fruit products and poultry, eggs and other fresh meats. Again, in this case, results do not significantly differ from previous studies, taking into account again that sample periods and food categories are different. Garcia-Muros et al., (2017) found Fruits (1.02) and Vegetables (1.03) to be slightly expenditure elastic. Similarly, Molina (1994) and Laajimi et al. (1997) found fruit and vegetables to have expenditure elasticity of 1.333 and 1.034, respectively, in Spain. Contrary to our results, Garcia-Muros et al., (2017) found poultry to be inelastic (0.850). However, Molina (1994) and Laajimi et al. (1997) summed all meat into one category and found meat consumption to be expenditure elastic in Spain.

[13] Taking into account how price indices were calculated based on unit values, and as the households choose prices and budget-shares simultaneously, following Dhar et al. (2003) we performed a Hausman test for price endogeneity by comparing the OLS estimated model with 3SLS estimator including region and nationality as instruments. Results indicated that endogeneity was not an issue in our model.

[14] For comparative purposes, we have provided the elasticity estimates for the QUAIDS model in the Appendix 2A.

Table 2-5 also shows the own price elasticities at the sample means. All own-price elasticities estimates are statistically significant at the 5% level and negative, except for beef, veal and lamb and the residual category, which are significant at the 10% level.

All food categories have absolute price elasticities less than unity, except for the residual food category. We found price elasticities for fruit and fruit products and vegetable and vegetable products to be -0.75 and -0.65, respectively. This is in line with the previous findings from Molina (1994) and Laajimi et al. (1997), although both studies combined fruits and vegetables into one single category and found price elasticities to be -0.68 and -0.84, respectively.

All animal and dairy products were found to be price inelastic. Beef, veal and lamb had the lowest price elasticity (-0.16). However, this result is consistent with previous studies in Spain using cross-section data. For instance, Garijo et al. (2008) found a price elasticity for all meats, jointly considered, of -0.399, which corresponds to the average of all price elasticities found in this paper for meat products.

In relation to cross-price elasticities (Table 2-5), we have found 150 complementarities among food categories and 115 substitutions. Most of the cross-price elasticities are significant and plausible. For instance, we found that poultry, eggs and other fresh meat category is a close substitute for all animal products including fish and marine products. We also found complementarity between all animal products and fruits and fruit products. Grains and grain based products and vegetable and vegetable products are complement to all animal products, starchy roots, tubers, legumes, nuts and oil seeds. Finally, milk and other dairy products were found to be complementary to cheese.

Table 2-5 Marshallian price elasticities at mean values

Food category	Grains	Vegetables	Pulse, Legumes and Starchy roots	Fruit and vegetable juices	Beef, veal and lamb	Pork	Poultry, eggs, other fresh meat	Processed and other cooked meats	Fish and other seafood	Milk, dairy and milk product imitates	Cheese	Sugar and confectionary and prepared desserts	Plant based fats	Composite dishes	Snacks and other foods	Residual category	Food Expenditure Elasticity
Grains and grain-based products	-0.29**	-0.18**	-0.04	-0.26**	-0.06	-0.10	-0.10**	-0.03	-0.04	-0.19**	-0.04	0.02	-0.06	-0.01	0.10	0.64	0.96 **
Vegetables and vegetable products	-0.10	-0.65**	0.05	-0.01	-0.05	-0.09	-0.17**	-0.10	0.32**	-0.14**	0.10	-0.11	-0.17	-0.11**	-0.10	0.31	1.21 **
Starchy roots, tubers, legumes, nuts and oilseeds	-0.05**	-0.15**	-0.61**	-0.20**	0.07**	0.02	-0.06**	-0.09**	-0.04*	-0.19**	0.05*	-0.07**	-0.11**	-0.10**	0.06	0.07	0.78 **
Fruit and fruit products	-0.21**	0.19**	0.34**	-0.75**	-0.18	0.32**	0.09**	0.31**	-0.04	-0.04	-0.05	0.02	0.36**	-0.06	0.01	-0.48	1.08 **
Beef. veal and lamb	-0.06*	-0.16**	0.10**	-0.24**	-0.16*	-0.22**	-0.04**	-0.10**	0.01	-0.21**	0.01	0.00	-0.01	-0.04**	0.11	0.11	0.92 **
Pork	-0.08**	-0.17**	0.04	-0.19**	-0.21**	-0.80**	-0.03**	-0.18**	-0.13**	-0.21**	-0.07	-0.02	0.00	-0.03*	0.22*	0.70**	0.94 **
Poultry, eggs, other fresh meat	-0.08**	-0.21**	0.07**	-0.17**	0.09**	0.12**	-0.85**	0.08**	0.01	-0.15**	0.07**	0.06**	0.05**	0.11**	0.11**	0.09	1.08 **
Processed meats products	-0.04	-0.18**	-0.13**	-0.16**	-0.13*	-0.28**	-0.01	-0.34**	0.15**	-0.23**	0.03	-0.07*	-0.12*	-0.04**	0.08	0.13	0.91 **
Fish and seafood	-0.03	-0.03	0.00	-0.22**	0.10	-0.21**	-0.04**	0.21**	-0.40**	-0.20**	-0.11	0.00	-0.04	-0.06	-0.13	-0.50	0.99 **
Milk and dairy products	0.03	-0.05	0.20**	-0.05	-0.05	-0.06	0.10**	-0.16**	-0.02	-0.64**	0.17**	-0.01	-0.10	0.12**	0.29**	0.39	0.99 **
Cheese	-0.05	-0.14	0.09**	-0.23**	0.02	-0.08	-0.04**	0.00	-0.09**	-0.19**	-0.26**	0.05	0.13*	-0.01	-0.06	-0.60**	0.86 **
Sugar and confectionary and prepared desserts	0.03	-0.19**	-0.10	-0.21**	0.11	0.06	0.01	-0.07	0.01	-0.20**	0.19**	-0.58**	-0.12*	0.05*	-0.06	0.23	0.80 **
Plant based fats	-0.07*	-0.19**	-0.15**	-0.17**	-0.01	0.01	-0.04**	-0.10**	-0.06	-0.22**	0.15**	-0.09**	-0.38**	-0.09**	0.05	0.35	0.84 **
Composite dishes	0.02	-0.19**	-0.21**	-0.23**	0.00	0.05	0.08**	-0.02	-0.06*	-0.16**	0.09**	0.07*	-0.11**	-0.47**	0.08	0.04	0.80 **
Snacks and other foods	-0.02	-0.16**	0.02	-0.22**	0.02	0.07*	-0.06**	-0.02	-0.07**	-0.20**	-0.04	-0.05**	-0.01	-0.04**	-0.67**	-0.07	0.61 **
Residual category	0.32	-0.09	0.13	-0.28	0.14	0.89**	-0.03	0.07	-0.30	-0.16	-0.62**	0.07	0.33	-0.02	-0.17	-1.79	0.90 **

**, * indicate significance at 5% and 10% respectively

Impact of a CO_2 Tax on Household CO_2-Eq Emissions and Food Consumption

Figure 2-1 shows, for the average household, the reduction in CO_2-eq emissions after the tax imposition, under the compensated tax scenarios, taking into account both price and cross-price elasticities. As can be observed, the mean reduction in emissions ranges from 2% to 6.4%, depending on the associated damage cost of emissions.

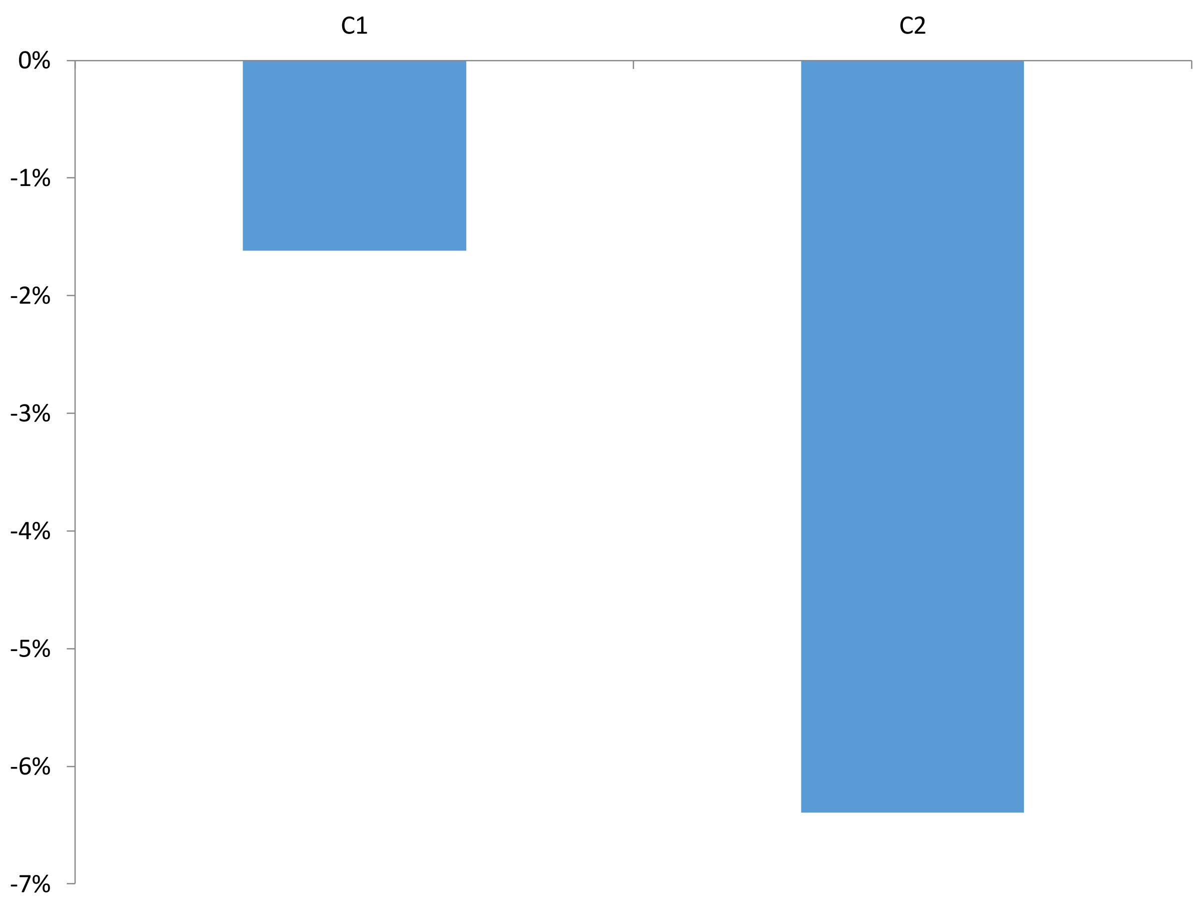

Figure 2-1 Mean reduction in CO2 equivalent emissions per person per day

Note: See Table 2-3 for a description of the different tax scenarios

Figure 2-2 shows the impact on the consumption of the different food categories considered in this study. The consumption of taxed food categories would decrease, particularly in the case of pork. The impact on beef and lamb would be lower in comparison with other studies, such as Henchion et al. (2014) and Säll & Gren (2015), as in the case of Catalonia, the beef, veal and lamb consumption is significantly price inelastic and its budget share is relatively low in comparisons with other meats. On the other hand, the consumption of subsidized food categories would increase. The magnitude of the increase highly depends on the public revenues from taxed products. As the public revenue from the taxed foods increases, the compensation to subsidized categories also increase generating higher consumption levels. This is particularly relevant in the residual category; snacks and other foods; and starchy roots, tubers, legumes, nuts and oilseeds category. Cheese consumption would increase despite the fact that it was taxed, which could be due to the strong complementarity with subsidized foods.

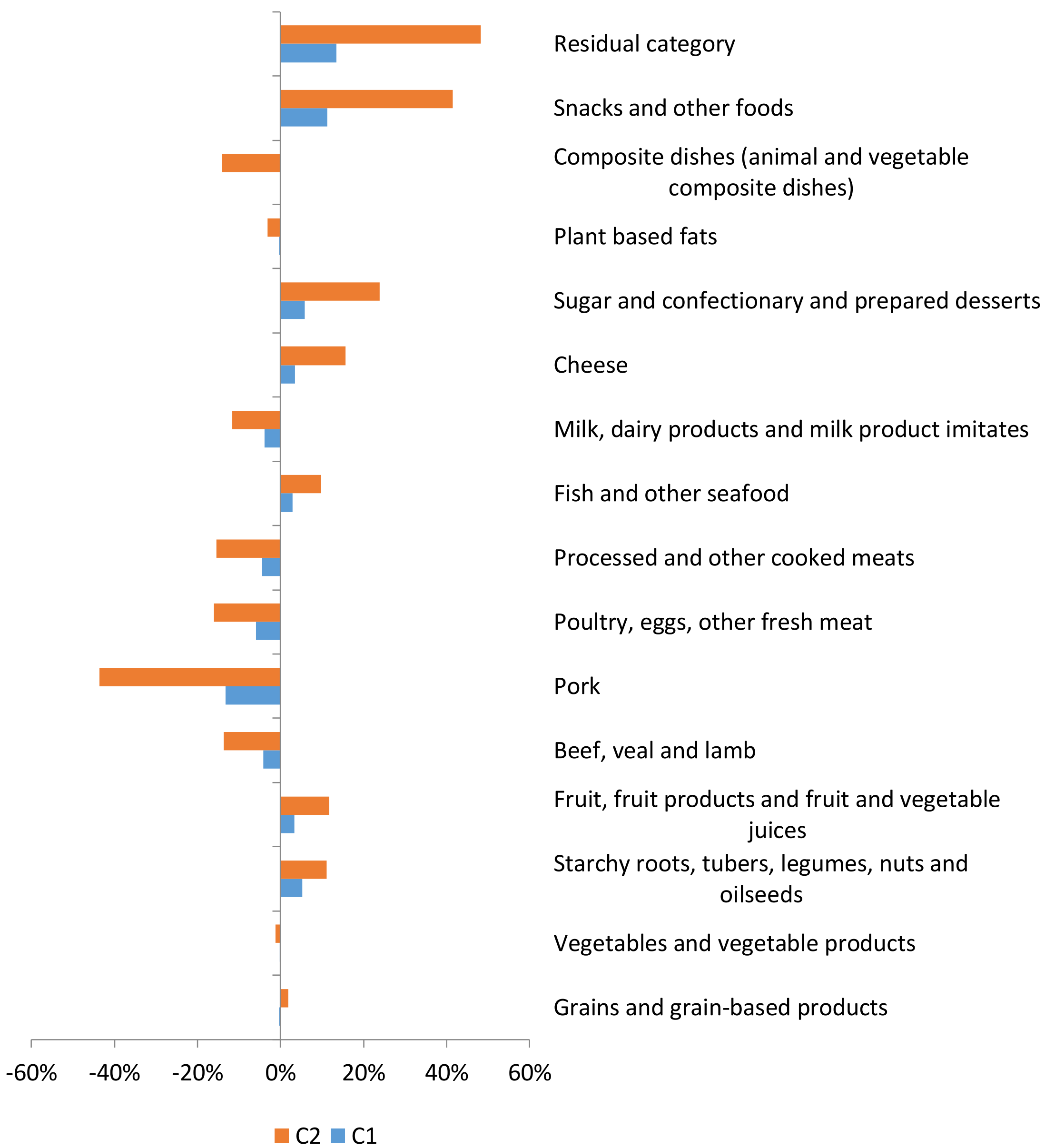

Figure 2-2 Reduction in consumption due to CO2 equivalent taxes

Note: See Table 2-3 *for a description of the different tax scenarios*

Welfare Impacts of CO_2 Equivalent Taxes

Welfare effects have been calculated using the compensated variation based on the log of the living cost index proposed by Lewbel & Pendakur (2009) for the average household, as well as for the different types of households, taking into account the socio-demographic characteristics that were included in the EASI demand system (the age of the household head and the presence of children).

The log of living cost index measures the change in the initial expenditure that a household should require to maintain the same food consumption level than before the imposition of the tax. In both scenarios, by definition, the public revenue generated is set to zero and it is allocated to subsidize food products with low CO_2-eq footprint. The first row in Table 2-6 shows the food expenditure compensation that the average household would receive due to price increases. Results indicate that in the first scenario (reducing carbon emissions by 20% by 2020), after the imposition of the taxes and subsidies, on average, consumers would save about 0.25% of their initial expenditure. In scenario C2 (reducing carbon emissions by 60% by 2050), consumers would require a slight increase of 0.41% in their initial expenditure to maintain their current consumption patterns.

Table 2-6 Welfare effects for different policy scenarios

	C1	C2
Average Household	-0.25	0.41
Head of the Household younger than 34 years	-0.10	1.14
Head of the Household between 35-49 years	-0.11	0.98
Head of the Household between 50-64 years	-0.24	0.13
Head of the Household older than 60 years	-0.50	-1.03
Presence of kids younger than 5 years old	-0.10	0.58
Presence of kids older than 5 years old	-0.02	1.16
No kids	-0.28	0.21

Note: See Table 2-3 for a description of the different tax scenarios

Table 2-6 also shows the distributional impact of the tax on different household groups. In scenario C1, all household groups save on their initial expenditure, however, the level of savings differ. For instance, in households without kids or when the household head is older savings would be higher than in other socioeconomic segments. Under scenario C2 (see Table 2-3 for definitions), all households except pensioners would require an increase in their initial expenditure to maintain the same food consumption level. Economically, scenario C1 would be more cost efficient for government and less regressive across different consumer groups.

Impact of CO2-eq tax on diet quality

To end with the impact assessment of the alternative tax scenarios, in this section we aim at reporting their potential effect on diet quality. Although there is a vast amount of literature about alternative measures for diet quality[15], here we have used a relatively simple approach by taking into account the 2005 Spanish Strategy for Nutrition, Physical Activity and Obesity Prevention (NAOS), which recommended that dietary proteins should provide between 10% and 15% of total calorie intake; total dietary fats should not exceed 30% of the daily caloric intake; and total carbohydrates should represent between 50% and 60% of the energy intake. As our dataset only contains household values, we have calculated average per capita adult equivalent values.

Figure 2-3 shows the main results from this analysis. The last two bars correspond to current nutrient ratios and the NAOS recommended values, respectively. The remaining bars correspond to each of the tax policy scenarios. Our result indicates that that the current macronutrient intake significantly exceeds the recommended values in the case of lipids (42.04%) and very slightly in the case of proteins (16.00%). Consequently, the intake of carbohydrates is lower than the recommended values (41.96%). These results are consistent with previous studies in Spain suggesting an overconsumption of fats (Moreno et al., 2002), which is one of the main reasons for the rapid increase of the prevalence of obesity and health-related diseases compared to other EU countries (Garcia-Goñi & Hernández-Quevedo, 2012).

Any tax policy to reduce CO_2-eq emissions would produce results that would either generate a more or less equilibrated diet depending on the policy scenario. Our results indicate that the total calorie intake would not significantly change in any tax scenario (the current caloric intake of 1.816 ± 512 Kcal/capita/day would decrease by 0.2% under scenario C1 but increase by 0.1%,

[15] The definition of diet quality and its empirical determination is beyond the scope of this paper.

under scenario C2. The impact on the quality of diet would be limited but would go in the right direction.

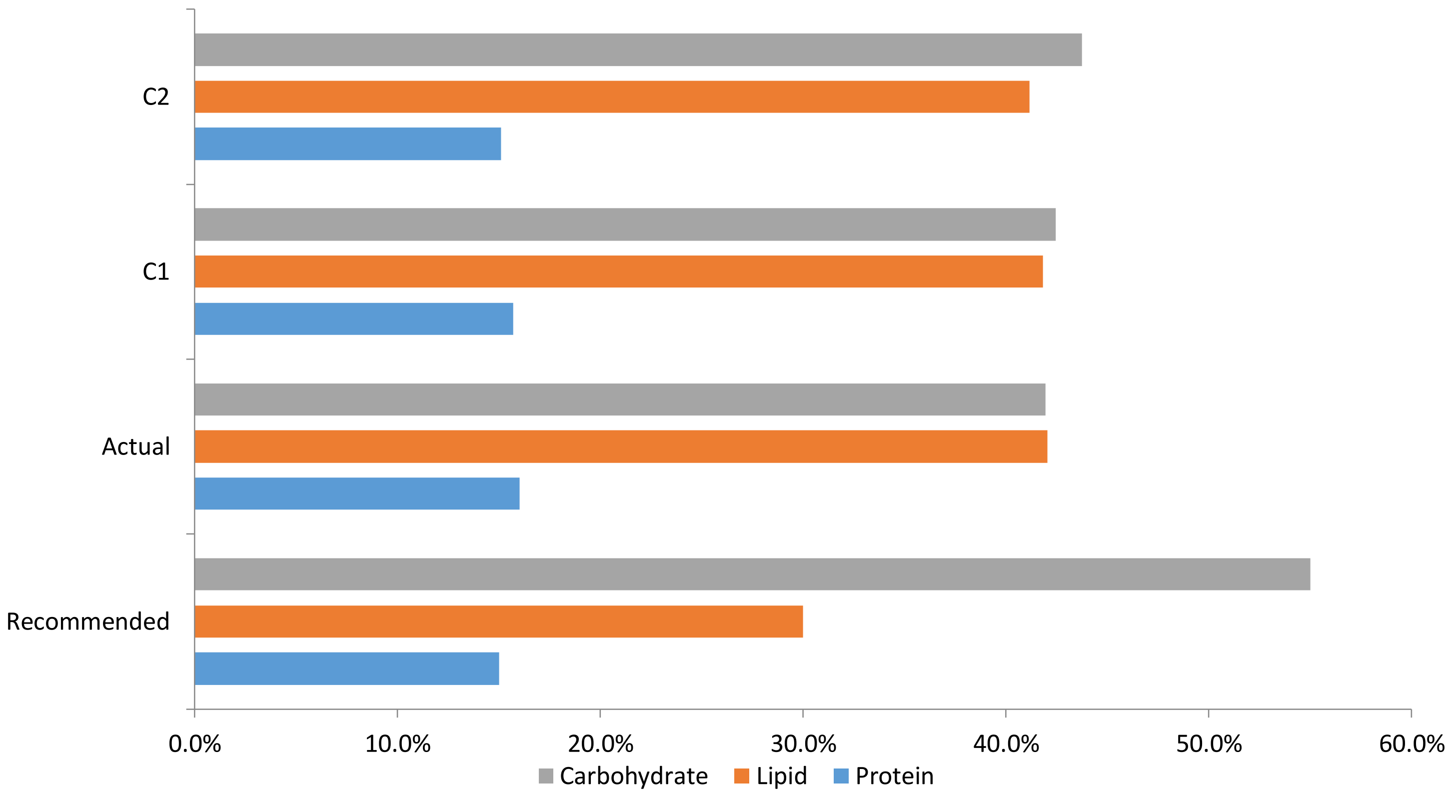

Figure 2-3 Impact of CO2-eq tax on diet quality

As Figure 2-3 shows, there would be a reduction in the intake of lipids and proteins together with an increase in that of carbohydrates. For instance, in scenario C2, the intake of proteins and lipids would decrease by 2% and 5.6%, respectively, while that of carbohydrates would increase by 4.3%. In order to complete the overview about the potential impact of the two tax scenarios, we have calculated the changes in the most relevant nutrients intake (Figure 2-4). Consistent with the previous results, changes are higher in scenario C2 (reducing carbon emissions by 60% by 2050). For instance, saturated fat and cholesterol intake would be reduced due to the reduction in the consumption of meat, composite dishes and lipids (Figure 2-2), while carbohydrates intake would increase. On the negative side, the sugar intake would increase due to the increase consumption of cereals and starchy roots as these food categories would be subsidized as a result of their low contribution to CO_2-eq emissions. Similarly, the consumption of healthy fatty acids like mono- and poly- saturated acids decreases. Summing up, our results suggest that CO_2 tax scenarios could lead to nutrient redistribution but not enough to meet the recommended dietary requirements in line with the NAOS strategy[16]. In addition, dietary changes result in trade-offs between healthy fatty acids such as mono-saturated and poly-saturated fatty acids and saturated fatty acid.

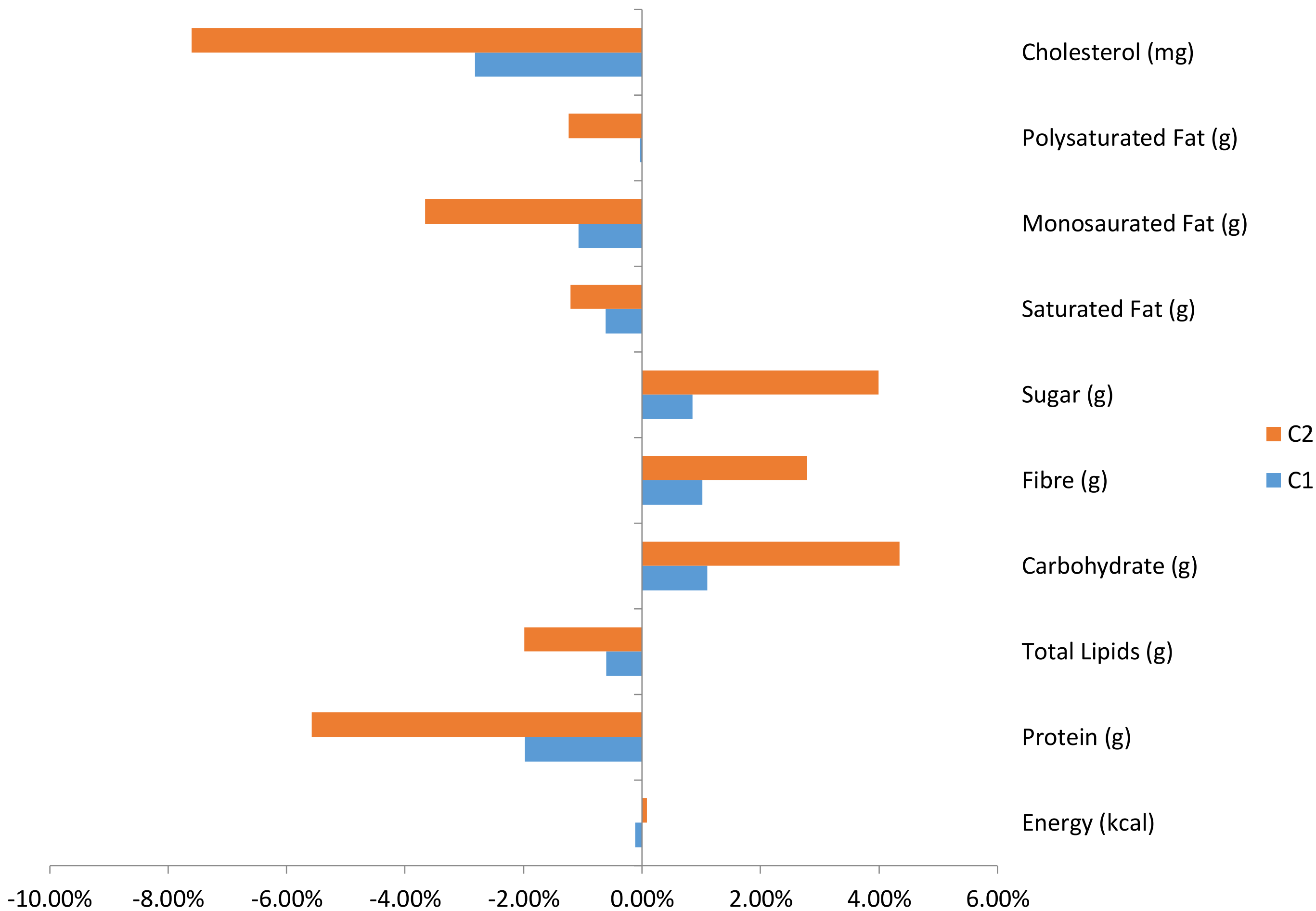

Figure 2-4 Impact of CO2-eq tax on nutrient compositions

2.4 Concluding remarks

The study aimed at assessing the impact of introducing a Pigovian or CO_2-eq tax on food demand, dietary composition, emission reduction and consumer welfare in Catalonia (Northeast Spain). Alternative tax policy scenarios have been considered, which, in essence, reflect the alternative social cost of emissions or alternative tax magnitudes. In any case, the scenarios have been chosen by taking into account real scenarios discussed in the EU. The methodological framework has been

[16] We have also carried out this analysis by social classes but we have not found any significant differences in relation to the average behaviour. Results are available from authors upon request.

based on food expenditure as well as on own- and cross-price elasticities calculated from estimating an EASI food demand system. From elasticity estimates, the paper has assessed the impact of the tax on CO_2-eq emission, diet quality and household's welfare.

Results obtained in this study suggest that taxing all food categories depending on their contribution to CO_2-eq emission would be unrealistic, as it would generate significant price changes, which would increase up to 55% (very far from their natural variation). Our analysis shows that a revenue neutral tax policy could be a plausible policy alternative for achieving green objectives at minimal consumer welfare impacts, also contributing to slightly improve the quality of diet. In any case, it is also evident that, by comparing the impact of the two scenarios considered in this study, the impact increases as the level of the tax increases, suggesting that the tax level should be large enough to generate significant reduction in CO2-eq emissions. In other words, tax policies should be implemented as a complementary measure to efficiently reduce such emissions.

A policy setback from our study could be border trade problems. The significant differential between the prices of products sold in Catalonia, after the carbon tax imposition, and the same products sold in neighbouring regions or countries could trigger a similar effect like the Danish fat tax (see Vallgårda et al. 2015). If the tax is only applied to Catalonia[17], consumers would like to bypass the tax by shopping from neighbouring regions and, to a lesser extent, from France if the transaction cost plus the non-taxed price is lower than the price paid for in Catalonia. If the tax is applied in all Spain, the effectiveness for Catalonia would be higher as cross-border trade will take place only with south-east of France and the most populated towns are located more than one hundred kilometres from the border, making transaction costs high enough to compensate price differentials.

In any case, results from this study only apply to Catalonia and similar analyses that consider all food categories should be conducted for the country as a whole. Despite the contribution of this study to the policy discussion, we must recognize that our results should be interpreted with caution for several reasons: the most important is the lack of data. Although there are many studies on life-cycle analysis, most of them are product specific and no existing study covers a wide range of products in Catalonia using a common methodological approach. Second, we have assumed that

[17] Catalonia introduced only in its territory a sugar tax on soft drinks in 2018

the food supply is perfectly inelastic by ignoring potential strategic decisions of firms. Further research could be focused on relaxing this assumption. Finally, authors have assumed, due to data unavailability, a strong separability between food-at-home and food-away-from-home, other durable and non-durable goods. On the other hand, this limitation is difficult to overcome as we would need, at least, a composite indicator of GHG emissions of other durable and non-durable goods. Despite these limitations, this study provides some evidence about the potential impacts of imposing a CO_2-eq tax on food products and welfare in Catalonia.

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CHAPTER 3
Effects of Fiscal Policies addressed to Internalize the Social Cost of Obesity in Spain

3.1 Introduction

After the UK, Spain has the highest prevalence rate of obesity in the EU (OECD, 2012). The last available National Health Survey showed that in 2011–2012 the prevalence of overweight and obesity among Spanish adults was 53.7% (ENIDE, 2012). WHO (2009) estimates show that overweight and obesity are responsible for 44% of diabetes, 23% of ischemic heart disease and 7–41% of certain cancer burdens. Treatment of obesity and related diseases has therefore resulted in higher cost of achieving better quality of life, as well as government expenditure on health care (Thiele and Roosen, 2018). For instance, in Spain obesity accounts for 7% (5 billion Euros) of the total government expenditure in the health sector (Vázquez and López, 2002).

Market interventions are traditionally justified to correct for such market failures, that is, externalities associated with increased health care and insurance costs borne by others (Cawley, 2004). For effective public response to public policies that aim to improve the quality of diet and reduce obesity, Nestle (2002) suggests five simultaneous changes in public policy: 1) educational reforms; 2) food labelling and advertising reforms; 3) health care and training requirements; 4) transportation and urban facilities requirements; 5) and tax policy reforms (i.e. increasing taxes on unhealthy foods and subsidies for healthy ones). The first four (1–4) policies have already been applied in Spain. Spanish public authorities, however, have been reluctant to implement tax reforms on unhealthy foods/nutrients. The only exception to this has been the imposition of a "soda-tax" on sugar-sweetened beverages (SSB) by the Catalonian Government (Northeast Spain) since the 1st of May 2017. However, the goal was to generate revenue for the government. We suggest that government can use this policy as an effective way of internalizing the public health cost that obesity imposes on government. As a result, internalizing the public health cost of obesity through tax and subsidy reforms on unhealthy and health foods will be the focus of this empirical study.

A few countries in Europe have implemented food/nutrient taxes with the goal of reversing the soaring prevalence rates of obesity: Hungary, in 2011, on SSBs, energy drinks, confectionaries, chocolate and salty snacks (Escobar et al., 2013); Finland, in 2011, on SSB, ice-creams, chocolates and confectionary; and France, in 2012, on sugar sweetened beverages and energy drinks (Berardi et al., 2016). Denmark has been the first country to introduced a tax on saturated fat (nutrient tax), which was implemented in October 2011 (Jensen et al., 2016; Smed, 2012) and abolished in 2012 after the imposition of the fat tax generated significant debate. Although, the objective of the saturated fat tax was to raise revenue for government, post-tax studies show the tax polices was effective in reducing fat consumption (Jensen et al., 2016; Smed, 2012).

Recent studies have towed the line of quantifying the public cost of obesity and related diseases (Finkelstein et al., 2003; Thorpe et al., 2004; Withrow and Alter, 2011). However, none of them has gone beyond this step by proposing a policy that could internalise these costs. We propose a VAT reform (based on fat composition of foods) that allows government to internalise the 7% of total annual health expenditure (Prospectivo Delphi, 1999; Vázquez and López, 2002) that obesity imposes on the health sector.

The EASI demand model of Lewbel and Pendakur (2009) is employed in analysing the effects of revenue-neutral tax reform policy on household food demand, as this model has been proven to be more flexible in relation to the functional form of the Engle curves and it is able to incorporate unobserved household heterogeneity in consumer welfare calculations. Price and expenditure elasticities obtained from the EASI demand model are converted into nutrient elasticities following Huang (1996) to assess the policy impact on consumers' quality of diet and nutrient redistribution. This study aims to contribute to existing literature by jointly considering the following four issues: 1) the estimation of the social cost of obesity from public health expenditure; 2) the internalisation of the social cost of obesity using a revenue-neutral (subsidize untaxed foods with revenues from taxed foods) policy simulation scenario to ensure that the potential effects of the tax are within the natural variation of the price change; 3) the effectiveness of the tax reform on food and nutrient demand are assessed by taking into account inter-relations between all food categories and nutrients consumed (not only within a food group or category); and 4) the welfare impacts of the tax on different consumer segments. Additionally, from an empirical point of view this is the first study that proposes a tax reform that seeks to internalise the public cost of obesity.

The remainder of this paper is organized as follows: the next section provides a description of methods i.e. data and an empirical methodology. In the third section, results and discussions of the analysis are presented, and finally the work is concluded with recommendations and limitations.

3.2 Methodological framework

Data

We obtained day-to-day household food purchase data from the 2012 Kantar Home scan panel, collated by the Kantar Worldpanel for the region of Catalonia. Each household that participated in the data collection process was given a scanner to scan the Universal Product Code (UPC) information of all products bought from retailers. Households also recorded, in a book, non-UPC items such as fresh fruits or vegetables, and in-store packaged breads and meats. The information retrieved from consumers includes purchase store type, price and weight of the product, unit of measurement (i.e. grams, litres or units), product-specific details (such as container type, barcode, and flavour) and household socioeconomic characteristics, such as nationality, age, social class, presence of children, number of pets, size of pets etc. Using the product-specific barcodes as the basic unit of aggregation, quantities and expenditures for each food product were aggregated to the annual[18] level for each household. From the panel of 1,146 households, a static panel of households that had remained in the sample for at least 42 weeks were considered for our analysis (655 households). In Spain, the Ministry of Agriculture provides nutritional guidelines on how foods should be aggregated for academic and health studies. Based on these guidelines, 20 food aggregates exist; however, due to data limitations we considered 16 food aggregates for our empirical estimation (see **Table 3-1**).

For ease of estimation, all prices and quantities were converted into Euros and kilograms. To move from the annual panel to cross-sectional data, prices for each respondent were aggregated using barcodes as the basic unit of aggregation (see Zhen et al., 2014). The barcodes were also used to put each product into subgroups and then into one of the 16 food groups, as shown in **Table 3-1**. To deal with the limitations of unit values from aggregating our price data, we followed Diewert (1998) to construct Fisher price indices[19] for each of the 16 food groups using the product barcodes.

[18] We have aggregated our static panel to cross-sectional data because of the difficulty of disentangling seasonal effects that span the one year under consideration and to mitigate the problem of zero purchases, which could not be handled with the double hurdle demand model due to convergence issues as we are dealing with a large number of food categories.
[19] Implementing the Fisher price index allows us to reduce the level of heterogeneity bias in the aggregation of our data in cross-sectional data and abstract out quality variation based on product heterogeneity (Silver and Heravi, 2006; Zhen et al., 2014).

In this case, the Fisher price index is the deviation of the price paid by a household relative to the average household in the year[20].

Table 3-1 Food expenditure shares and socioeconomic characteristics of households

	Variable	Mean	Std. Dev	Percentage of Zero Purchases
Expenditure Shares	Grains and grain-based products	6.59	3.76	0.0
	Vegetables and vegetable products	13.58	6.86	0.0
	Starchy roots, tubers, legumes, nuts and oilseeds	1.42	1.15	0.2
	Fruit and fruit products	21.62	9.33	0.0
	Beef, veal and lamb	2.15	1.66	2.1
	Pork	1.96	1.48	0.5
	Poultry, eggs, other fresh meat	6.59	6.71	0.3
	Processed meat products	3.91	2.35	0.0
	Fish and seafood	4.82	2.74	0.2
	Milk and dairy products	18.22	8.96	0.0
	Cheese	2.51	1.56	0.2
	Sugar and confectionary and prepared desserts	5.88	3.67	0.0
	Plant-based fats	2.57	1.77	1.8
	Composite dishes	5.23	4.03	0.5
	Snacks and other foods	0.72	0.83	2.4
	Residual category	2.13	1.55	0.8
Socio-demographics	High social class	0.37	0.48	
	Low social class	0.22	0.41	
	Lower middle social class	0.20	0.40	
	Middle social class	0.21	0.41	
	18–34 years	0.06	0.23	
	35–49 years	0.42	0.49	
	50–64 years	0.35	0.48	
	60+ years	0.17	0.38	
	Presence of children 0-5 years	0.13	0.34	
	Presence of children 5+ years	0.21	0.41	
	No children	0.66	0.47	
	Underweight	0.03	0.18	
	Normal weight	0.54	0.50	
	Overweight	0.14	0.35	
	Obese	0.28	0.45	

Source: Author's own computation, 2018

[20] The three-step procedure used in this study is described in Appendix 3A of the Supplementary File

Average expenditure shares and socio-demographic characteristics of the sample are presented in **Table 3-1**. Sample characteristics on **Table 3-1** shows that middle class households represent 41% of the sample, while households belonging to the higher and lower social classes represent 37% and 22%, respectively. Considering the BMI of the household head, underweight people were the minority (3.2%), while obese and overweight persons represented 42.6% of the total sample.

Estimating Food Price Elasticities

Price and expenditure elasticities were derived from a linear approximate EASI demand model (see Lewbel and Pendakur, 2009) as these authors suggested that the linear approximate EASI and full nonlinear EASI models generate extremely close parameter estimates. The budget share w_j of each food *j* is linear-in-parameters using:

$$\boldsymbol{w_j = \sum_{r=0}^{5} E_{rj}\tilde{y}^r + \sum_{k=1}^{J} A_{kj} lnP_k + \sum_{k=1}^{J} B_{kj} lnP_k \tilde{y} + \sum_{l=0}^{L} (C_{lj} z_l + D_{lj} z_l \tilde{y}) + u_j} \qquad (1)$$

where $\tilde{y}$ is real food expenditure. The regressors in (5) are a fifth-order polynomial in $\tilde{y}$, log prices lnP_k of each good *k* and L different demographic characteristics z_l, as well as interaction terms of the forms: $lnP_k\tilde{y}$ and $z_l\tilde{y}$. Parameters to be estimated are A_{kj}, B_{kj}, C_{lj}, D_{lj} and E_{rj}.

In the approximate EASI model, $\tilde{y}$ is specified as the Stone price-deflated real income: $\tilde{y}_i = \ln(x) - \sum_{j=1}^{J} \ln(P_{ij})\, \overline{w}_j$, where x_i is annual nominal household income, $\overline{w}_j$ is the mean budget share of good *j* and P_{ij} is the price of good *j* paid for by household i. For the model to be consistent with the theory, the budget share equations w_j are required to satisfy the properties of adding-up, linear homogeneity and Slutsky symmetry. The approximate EASI model consisting of 16 equations minus one was estimated using iterative linear three-stage least squares.

Two potential sources of endogeneity can be identified in (1). First, the presence of budget shares in the stone index makes this index endogenous.[21] Second, the real food expenditure $\tilde{y}$ is a function of the endogenous food group expenditure (x). To control for the second type of endogeneity in our conditional food-at-home demand model, we used residuals from an OLS regression of

[21] According to Lewbel and Pendakur (2009) and Zhen et al. (2014), this source of endogeneity in demand models is numerically unimportant.

expenditure on sociodemographic variables and their interactions as proxy for income to instrument for food group expenditure (x).[22]

Table 3-2 Tax and subsidy simulation scenarios

Food Categories	Fat tax Scenario					
	Annual consumption (Kg/person)	Gram/person/day	Average saturated fat content (g/100g)	VAT Rate	Share of damage cost/day (EUR)	Price change
Grains and grain-based products	26.67	73.06	0.82	4%	0.00	-1.19%
Vegetables and vegetable products	60.77	166.50	0.04	4%	0.00	-1.19%
Starchy roots, tubers, legumes, nuts and oilseeds	6.68	18.31	1.34	4%	0.00	-1.19%
Fruit, fruit products and fruit and vegetable juices	93.55	256.29	0.00	7%	0.00	-1.19%
Beef, veal and lamb	9.13	25.02	3.50	10%	0.01	1.4%
Pork	8.52	23.34	3.06	10%	0.01	1.1%
Poultry, eggs, other fresh meat	31.18	85.43	3.55	10%	0.01	0.9%
Processed and other cooked meats	16.05	43.97	9.66	10%	0.04	3.7%
Fish and other seafood	21.07	57.74	0.69	10%	0.00	-1.19%
Milk, dairy products and milk product imitates	89.86	246.18	1.15	7%	0.00	-1.19%
Cheese	10.19	27.92	18.64	4%	0.07	7.2%
Sugar and confectionary and prepared desserts	23.86	65.38	8.82	10%	0.03	3.3%
Plant-based fats	11.31	30.99	23.11	10%	0.09	8.8%
Composite dishes	24.56	67.29	0.76	10%	0.00	-1.19%
Snacks and other foods	3.03	8.30	3.89	10%	0.02	1.5%

Expenditure elasticities and Hicksian and Marshallian price elasticities were derived from (1) following Castellón et al. (2015) and Zhen et al. (2014)[23]. The matrix of price and expenditure elasticities were converted into a matrix of nutrient elasticities (see Huang, 1996) to analyze the

[22] Zhen et al. (2014) show that this form of endogeneity can be handled by estimating an incomplete food-at-home demand model and ignoring the need to use instruments. However, this strategy needs information about household income, which is not available in our dataset.
[23] See Appendix 3B

effects of the VAT reform on nutrient ratios and nutrient distribution. Complete nutrient data[24] on all foods consumed in our data were obtained from the Spanish Food Composition Database (BEDCA)[25](see **Table 3-2**).

Tax Simulation Scenarios

Following the work of Salois and Tiffin (2011), this study simulates a revenue-neutral fiscal policy where a VAT reform is derived from a fat tax is imposed on foods based on their saturated fat content, while subsidies are placed on selected foods that are untaxed. The threshold for imposing the taxes was set at 2.3% of saturated fat following the work of Jensen et al. (2016) (the threshold considered by the Danish Government when designing its fat tax in 2011). As mentioned in the introduction, we proposed an increase of the current value added tax (VAT scenario) to internalize the externalities (public health expenditure[26]) associated with obesity in Spain, which accounts for about 7% of total health expenditure (approximately 5 billion Euros). This is equivalent to an average damage cost of 0.29 Euros per person per day. The damage cost was proportionally distributed based on the saturated fat content on all food categories with saturated fat exceeding 2.3%.

Hence, the tax imposed on each food category with saturated fat above 2.3% was calculated as:

$$\boldsymbol{VAT\ scenario}: \boldsymbol{t_j} = \left(\boldsymbol{\xi_j} * \boldsymbol{\tau_1}\right) \tag{2}$$

where $\boldsymbol{\xi_j}$ is the average saturated fat contained in food group *j*, $\boldsymbol{\tau_1}$ is the damage cost due to rate to the VAT tax.

In creating the revenue-neutral tax scheme, we followed the paper of Edjabou and Smed (2013) to estimate the price of the subsidized food aggregate *k*, $\boldsymbol{P_{1k}}$ as:

$$\boldsymbol{P_{1k}} = \boldsymbol{p_{0k}} - \emptyset * \boldsymbol{P_{0k}} \tag{3}$$

where $\emptyset$ is a consistently positive factor and $\boldsymbol{P_{0k}}$ is the price of the *k*-th food category that was untaxed in VAT scenario (**Table 3-2**). The value of $\emptyset$ is determined as the subsidy that makes the

[24] This was calculated as the weighted mean using the frequency of purchase as weights. The entire table, comprising the 44 nutrients and 15 food categories considered in our paper, are available upon request.

[25] Further information can be retrieved from http://www.bedca.net/bdpub/index.php.

[26] In 2016, the Spanish Health Expenditure was 71.48 billion Euros, with 7% representing 5 billion. From this calculation, in 2016 the government spent in excess of 5 billion on health due to direct and indirect consequences of obesity. See https://datosmacro.expansion.com/estado/gasto/espana

total tax revenue from the taxed foods equal to zero. Based on the above method, the subsidies ($\emptyset$) generated for the VAT scenarios ($\emptyset_{VAT}$) = 1.2%. The taxes computed are displayed in **Table 3-2**.

Change in Food Consumption and Nutrient Intake

The percentage reduction in the quantity of food products and nutrients consumed after imposing the tax were calculated taking own- and cross-price elasticities into account. The change in quantity demanded for each aggregated food group was calculated as:

$$\frac{\Delta \boldsymbol{Q_j}}{\boldsymbol{Q_j}} = \sum_{\boldsymbol{k=1}}^{\boldsymbol{J}} \boldsymbol{\varepsilon_{kj}} * \frac{\Delta \boldsymbol{p_k}}{\boldsymbol{p_k}} \tag{4}$$

where $\frac{\Delta \boldsymbol{p_k}}{\boldsymbol{p_k}}$ and $\frac{\Delta \boldsymbol{Q_j}}{\boldsymbol{Q_j}}$ represent the percentage change in prices and quantities of each food group after the tax respectively (Säll and Gren, 2015) and $\boldsymbol{\varepsilon_{kj}}$ is the own- and cross-price elasticities of the aggregate food group *j*.

Finally, the post-tax change in the consumption of nutrients for the average household, $\frac{\Delta \boldsymbol{q_n}}{q_n}$, taking into account own- and cross-price nutrient elasticities, was calculated as:

$$\frac{\Delta q_n}{q_n} = \sum_{\boldsymbol{k=1}}^{\boldsymbol{J}} \boldsymbol{\Psi_{kj}} * \frac{\Delta \boldsymbol{p_k}}{\boldsymbol{p_k}} \tag{5}$$

where $\boldsymbol{\Psi_{kj}}$ is the own- and cross-nutrient elasticities of good *j* and $\frac{\Delta \boldsymbol{q_n}}{\boldsymbol{q_n}}$ is the percentage change in nutrient *n*.

Distributional Effects on Nutrient Consumption

The distributional effects of the tax reform on nutrient intake were analysed following Leicester and Windmeijer (2004). The policy effects were analysed in the context of changes (decline or increase) in both the consumption of selected essential macronutrients (protein, carbohydrate, lipids and protein) and micronutrients (cholesterol, saturated fats, mono-saturated fats, and sodium) for the average household and two sociodemographic household segments i.e. the age and the body mass index (BMI) of the household head (see **Table 3-1**).

Welfare Effects of the Tax Reform

The welfare effects are analyzed from the context of age and the BMI of the household head. To do this, we have implicitly assumed that food supply in this economy is perfectly elastic and that production decisions are not influenced by the VAT reform. Welfare estimates based on compensating variation were calculated using the log of living cost index (Lewbel and Pendakur, 2009) which takes into account both first-order and second-order effects. The log of living cost index for the average household can be estimated using:

$$\boldsymbol{C}(\boldsymbol{p_1}, \boldsymbol{u}, \boldsymbol{z}, \boldsymbol{\varepsilon}) - \boldsymbol{C}(\boldsymbol{p_0}, \boldsymbol{u}, \boldsymbol{z}, \boldsymbol{\varepsilon}) = (\boldsymbol{p_{k1}} - \boldsymbol{p_{k0}})'\boldsymbol{w_0} + \mathbf{0.5}(\boldsymbol{p_{k1}} - \boldsymbol{p_{k0}})'\left(\sum_j^N \boldsymbol{A_{kj}} + \boldsymbol{B_{kj}}\bar{\boldsymbol{y}}\right)(\boldsymbol{p_{k1}} - \boldsymbol{p_{k0}}) \quad (6)$$

The term $(\boldsymbol{p_{k1}} - \boldsymbol{p_{k0}})'\boldsymbol{w_0}$ in (6) is the Stone index for the price change while $\mathbf{0.5}(\boldsymbol{p_{k1}} - \boldsymbol{p_{k0}})'\left(\sum_j^N \boldsymbol{a_{kj}} + \boldsymbol{b_{kj}}\tilde{\boldsymbol{y}}\right)(\boldsymbol{p_{k1}} - \boldsymbol{p_{k0}})$ models substitution effects resulting from price changes.

To estimate the welfare effects for the *n*-th social demographic group, we subsampled the data based on the *n*-th demographic group to estimate average budget shares, which were introduced into equation (6).

3.3 Results and Discussion

Food Demand and Nutrient Elasticities

Results indicated that a quintic functional form was appropriate to capture the curvature of the Engel curves. Similarly, Wald tests were carried out for the interactions between real food expenditure and prices, and demographic characteristics of households. The results indicated that interaction with real expenditure was jointly significant with a p-value<0.01, while interactions between price and sociodemographic variables were not jointly significant; hence, they were not included in the final model[27]. Mean Conditional food-at-home Marshallian price elasticities[28] for the average household and the household segments mentioned in the previous section are presented in Table 3-3. For the average household, we found all price elasticities to be negative and inelastic. Among the animal sources of protein, the beef, veal and lamb category and the pork categories were the most elastic, while fish was the least responsive to price changes. In relation to age, younger people (18–35 years) are more responsive to price changes in fruit, fruit products and fruit and vegetable juices, in the beef, veal and lamb category and in the pork categories than all other age groups. Older people (50–65+ years), on the other hand, are more responsive to price changes in cheese, and fish and seafood than younger people. With respect to the BMI of the household head, responses to prices do not follow a clear pattern and the two extreme segments (households with an underweight or obese head) tend to be more responsive to price changes.

[27] Results are not included due to space limitations but are available from authors upon request

[28] Conditional food-at-home Marshallian cross price elasticities and expenditure elasticities are shown on Appendix 3C. in the Supplementary File

Table 3-3 Mean Marshallian Food-at-Home Price Elasticities across different Ages and Body Mass Indexes

	Age: 18–35 years	Age: 35–49 years	Age: 50–64 years	Age: 65+ years	Under-weight	Normal weight	Overweight	Obese	Average
Grains and grain-based products	-0.49***	-0.56***	-0.54***	-0.45***	-0.48***	-0.53***	-0.50***	-0.57***	-0.53***
Vegetables and vegetable products	-0.64***	-0.52***	-0.60***	-0.64***	-0.64***	-0.56***	-0.58***	-0.61***	-0.58***
Starchy roots, tubers, legumes, nuts and oilseeds	-0.76***	-0.81***	-0.82***	-0.78***	-0.83***	-0.80***	-0.81***	-0.81***	-0.81***
Fruit and fruit products	-1.09***	-0.99***	-0.97***	-0.97***	-1.00***	-0.99***	-0.96***	-0.99***	-0.99***
Beef, veal and lamb	-1.08***	-0.95***	-0.88***	-0.93***	-0.95***	-0.93***	-0.89***	-0.94***	-0.93***
Pork	-1.03***	-0.98***	-0.96***	-0.97***	-0.98***	-0.97***	-0.96***	-0.98***	-0.97***
Poultry, eggs, other fresh meat	-0.56***	-0.49***	-0.54***	-0.67***	-0.46***	-0.55***	-0.53***	-0.55***	-0.54***
Processed meat products	-0.54***	-0.52***	-0.35***	-0.31***	-0.36***	-0.43***	-0.39***	-0.48***	-0.44***
Fish and seafood	-0.16	-0.23*	-0.34***	-0.39***	-0.30***	-0.26***	-0.26***	-0.37***	-0.30***
Milk and dairy products	-0.65***	-0.65***	-0.53***	-0.48***	-0.67***	-0.61***	-0.56***	-0.54***	-0.58***
Cheese	-0.84***	-0.94***	-0.99***	-0.94***	-0.91***	-0.95***	-0.99***	-0.94***	-0.95***
Sugar and confectionary and prepared desserts	-0.93***	-0.91***	-0.87***	-0.87***	-0.91***	-0.90***	-0.88***	-0.89***	-0.90***
Plant-based fats	-0.12	-0.41***	-0.49***	-0.43***	-0.38***	-0.40***	-0.52***	-0.45***	-0.43***
Composite dishes	-0.67***	-0.71***	-0.65***	-0.51***	-0.54***	-0.67***	-0.71***	-0.65***	-0.67***
Snacks and other foods	-0.70***	-0.71***	-0.48***	-0.29**	-0.69***	-0.63***	-0.59***	-0.54***	-0.61***
Residual category	-1.27	-0.99	-0.79	-0.92	-1.01	-0.94	-0.80	-0.95	-0.93

******, **, * indicate significance at 1%, 5% and 10% respectively.***

Results for nutrient expenditure and price elasticities are shown in Appendix 3D. In the case of Catalonia, our results indicate that protein, potassium, selenium, vitamin C, niacin, vitamin B6, folate acid, choline and vitamin B12, alpha carotene, beta carotene, beta cryptonym, lycopene (µg), vitamin D, vitamin K and cholesterol are expenditure elastic, while all other nutrients are expenditure inelastic. Considering the impact of price changes on the demand for nutrients, the results indicate that an increase in the price of grains and grain-based products, vegetables and vegetable products, and fruit and fruit products will reduce the consumption of fiber and sugar. Similarly, an increase in the price of all animal sources of protein, milk and dairy product imitates and cheese will lead to a reduction in the consumption of lipids. In terms of cholesterol intake, an increase in the prices of pork, poultry and other fresh meat, and processed meats will result in the reduction of cholesterol intake. The intake of protein declines when the prices of all animal food categories and composite dishes increase. Finally, an increase in the price of vegetables and vegetable products and fruit and fruit products will result in a decline in vitamin C intake.

Impact of the Fat Tax on Daily Consumption

The impact of the policy reform on the average household's daily consumption is shown in **Figure 3-1**. The consumption of fat-dense foods, such as processed and other cooked meats, cheese, and plant based fats, decreased significantly. Similarly, the consumption of sugar-dense foods such as snacks and other foods reduced but marginally. Surprisingly, the consumption of beef, veal and lamb and pork increased despite the tax imposition. Appendix 3D shows that this could be due to the strong complementarity between these foods and subsidized foods i.e. Grains and grain-based products, Vegetables and vegetable products; and Fruit and fruit products. In addition, this suggest that not considering inter-relations among all food categories in household demand analysis when simulating fiscal policies is likely to lead to wrong estimation of the potential impact of the tax (Mytton et al., 2007). The consumption of vegetables and vegetable products, and fruit, fruit products and fruit and vegetable juices increased significantly due to the subsidies imposed. Our results are consistent with those of Mytton et al. (2007), who showed that fat taxes produce modest but meaningful changes in food consumption oriented towards a reduction in the prevalence of cardiovascular diseases.

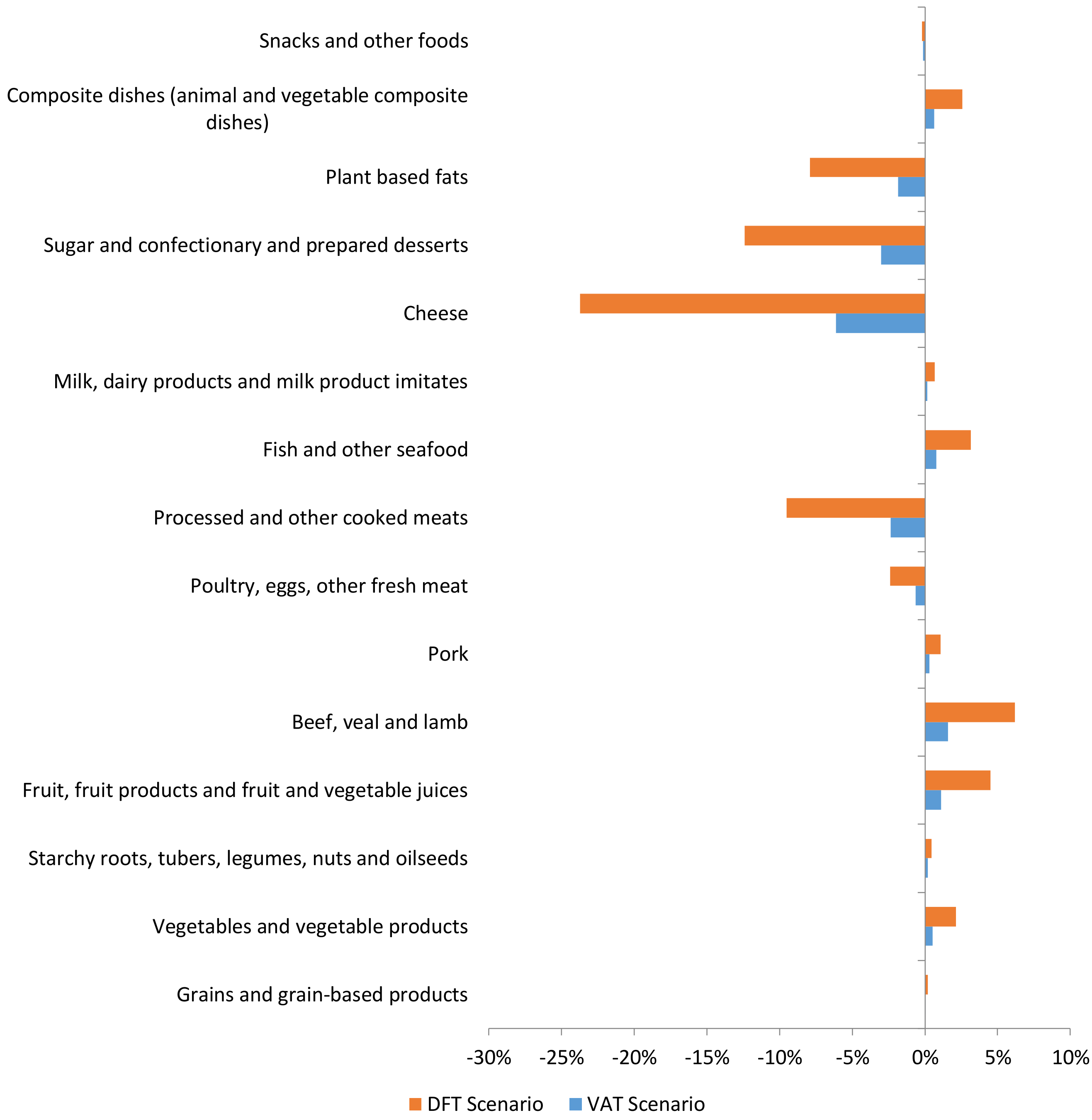

Figure 3-1 Changes in food consumption due to taxes

Impact on Nutrient Redistribution

In Spain, the Estrategia para la Nutrición, Actividad Física y Prevención de la Obesidad (NAOS) (2005) recommended a maximum protein intake of 15% of total calories; total fat (lipids) not exceeding 30% of the total daily calorie intake; and average carbohydrate intake representing 55% of total calorie intake. Based on these estimates, we are able to compare recommended average per capita adult equivalent nutrient ratios with pre- and post- tax nutrient ratios. Results presented in **Figure 3-2** shows that, starting from the bottom, the first and second group of bars correspond to the NAOS recommended and pre-tax nutrient ratios, respectively, while the third group of bars represents the post-tax nutrient ratios. The current average Spanish diet is clearly unbalanced. In fact, current lipid and protein intake are over their recommended values, representing 44.96% and 19.76% of total daily caloric intake. The carbohydrate intake, on the other hand, is lower than the recommended value (35.28%) of total daily caloric intake. Imposing the tax generates a marginal but positive impact on the quality of the diet in the sense that macronutrient ratios are calibrated toward the recommended ratios. The ratios of lipids in total calorie intake decreased by 0.70%, while the ratio of carbohydrate increased by 0.70%. Even the calorie intake from protein is higher than the recommended, the consumption of protein appreciated by 0.36%. Since the objective of the tax was internalizing the damage cost of obesity, it can be concluded that the policy was effective; however, the impact is significantly lower. Similar results were found for UK by Tiffin and Arnoult (2010) who concluded that taxing saturated fat (0.00–15%) and subsidizing fruits (14.78%) was insufficient to achieve the goal of nutrient redistribution.

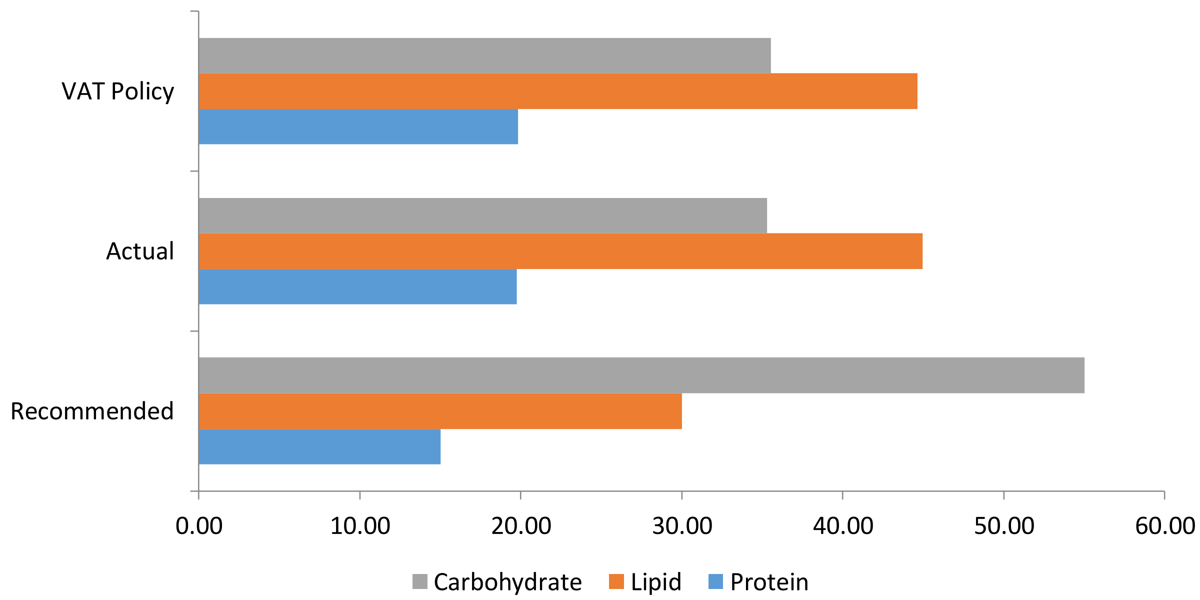

Figure 3-2 Impact of tax policies on dietary ratios

The impact of the tax is also analyzed in the context of changes in micronutrient intake, such as sodium, saturated fat, mono-unsaturated fatty acid, poly-unsaturated fatty acid and cholesterol, which have been proven to be associated with the prevalence of some types of diabetes and cardiovascular diseases.

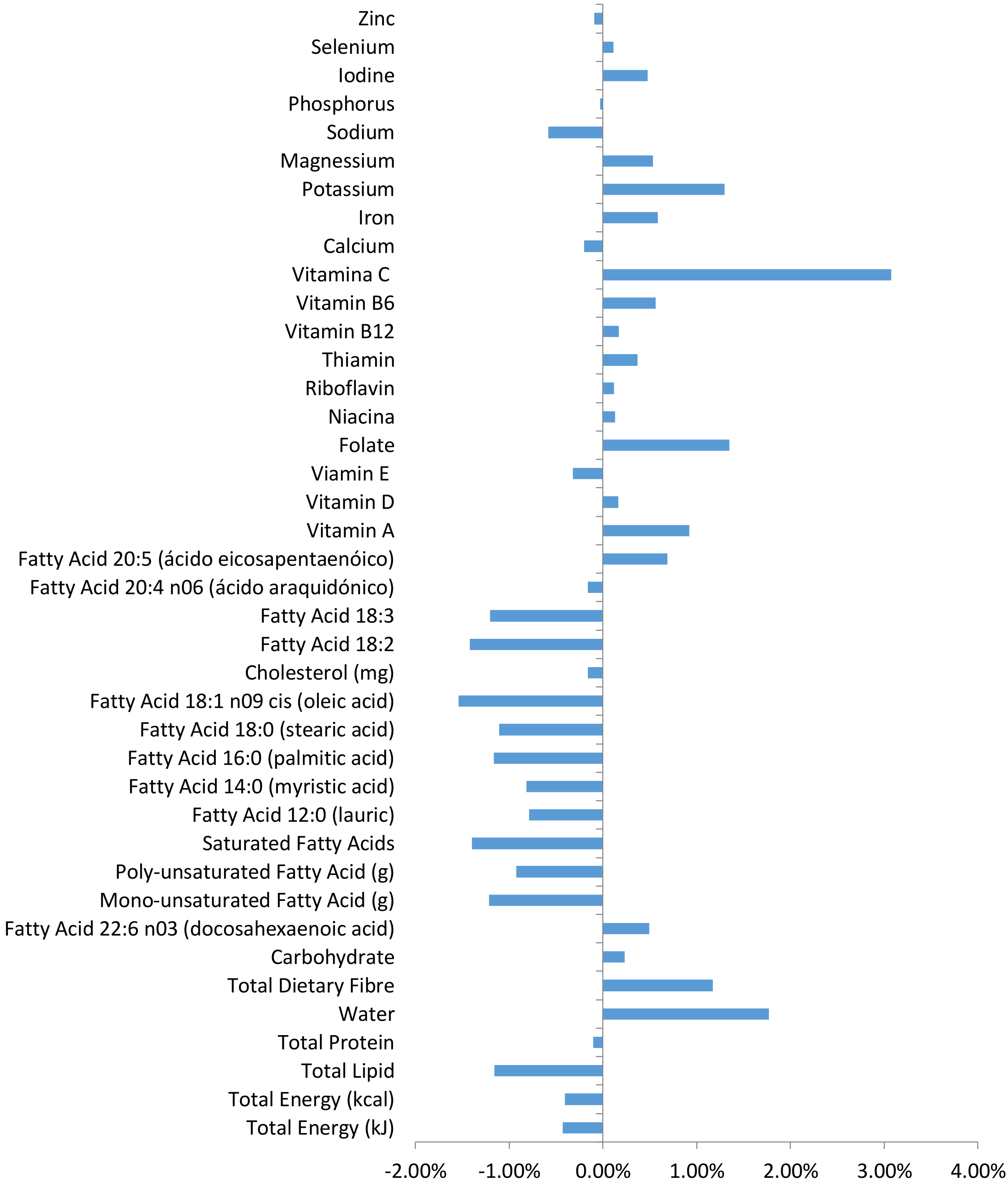

Figure 3-3 Impact of tax policies on nutrient distribution

Result from **Figure 3-3** indicates that the consumption of saturated fats, mono-saturated fatty acid, sodium and cholesterol would decrease by 1.39%, 1.22%, 0.58% and 0.61%, respectively. However, this positive effect is offset by the decrease in the beneficial fatty acid – poly-unsaturated fatty acid – by 0.93%. This is because products with relatively high poly-unsaturated fatty acid are usually the main sources of saturated fatty acids. The fiscal policies would also have a significantly positive impact on non-targeted nutrients such us dietary fiber, iron, vitamin C, potassium, magnesium, vitamin B6, alpha and beta carotene etc. In summary, a tax policy based on the damage cost of obesity could lead to a marginal reduction of health threatening nutrients.

Nutrient Intake and Distributional Impact of the Fat Tax

Age of household heads

From the age context, energy intake decreased for all age groups; the decline increases with decreasing age of the household head (see **Figure 3-4**). The reduction in lipid intake was highest among household heads lying between 50 and 64 years and lowest for the youngest segment (18–34 years).

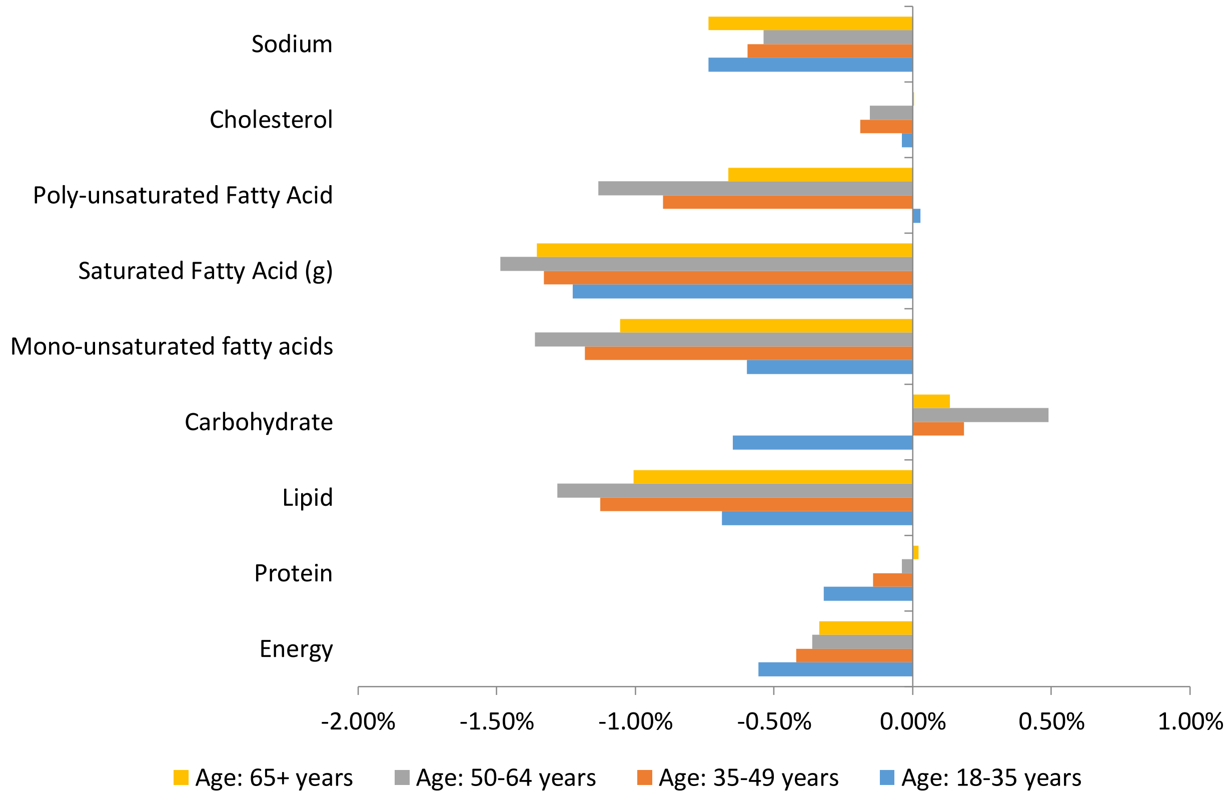

Figure 3-4 Welfare effects of fiscal policy across different age

The tax improves the health of all households by reducing the total daily cholesterol and saturated fat intake by 0-0.19% and 1.23-1.49%, respectively. Protein consumption decline across all ages with the exception of household heads 65 years and above. In terms of sodium intake, younger household heads (18–34) and household heads 65 years and above were more positively affected by the fiscal policy than the segment between 35 and 64 years. Summing up, even though the effect of the tax was marginal, we cannot ignore the positive impact of the tax/subsidy schemes across all age segments especially on saturated fat and total lipid intake. In terms of poly-unsaturated fat consumption, the tax is regressive on households with average age above 35 years as they tend to spend more on less nutrient energy dense foods that are detrimental to their health.

BMI of household heads

In general, tax policy reform would be positive, especially for obese and overweight household heads in terms of lipid and carbohydrate intake (see **Figure 3-5**). For instance, lipid intake would be reduced by 0.98% for underweight persons and 1.32% for overweight persons. However, carbohydrate intake would decrease by 0.05% for underweight individuals but increase by 0.60% for overweight persons. In terms of the micronutrient intake, the fiscal policy would potentially improve the quality of diet of all the BMI groups by reducing cholesterol, sodium and saturated fat intake especially for persons with obesity. On the other hand, there would be some negative effects associated with decrease in beneficial fatty acids such as poly-unsaturated fatty acid intake. The tax policy would have a greater impact on persons with obesity, which are the most desired outcomes of internalizing the public cost of obesity. Similar to the age segments, even though tax policies are effective at reducing the intake of health damaging nutrients such as lipids, saturated fat, sodium, and cholesterol, there are unintended effects that do not improve consumer health.

Although the potential effectiveness of the fat tax policy is relatively low in reducing lipid intake, literature support that small reductions in fat intake can reduce body weight (Siggaard, Raben and Astrup, 1996); Swinburg et al., 1997). Yu-Poth et al. (1999) supported this view by showing that a 1% reduction in energy from total fat led to 0.28 kg decrease in body weight. Similarly, from a meta-analysis, Astrup et al. (2000) showed that a 1% reduction in dietary fat could lead to weight loss of about 0.37 kg (95% CI, 0.15 to 0.6 kg).

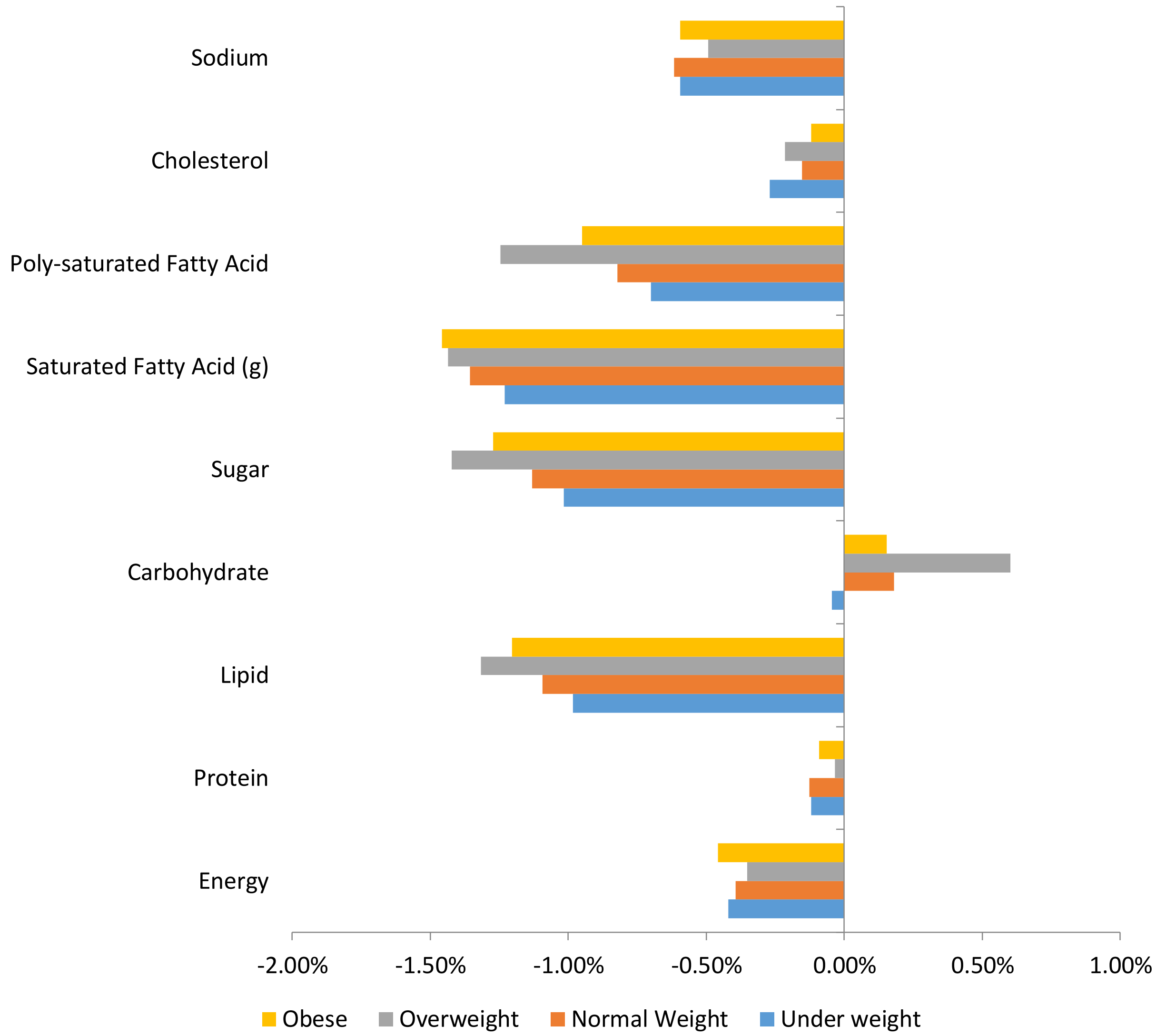

Figure 3-5 Welfare effects of fiscal policy across different ages

Welfare Effects of the Fat Tax

Welfare effects are displayed on Figure 3-6. The average household would save 0.03% of its initial expenditure on food due to revenue-neutral nature of the tax scheme. In the context of age segments, older households would save more on their food expenditure than younger households. From the BMI context, persons with obesity would save more on consumption than all other BMI groups. In conclusion, internalizing the damage cost of obesity does not put economic burden on the average individual as well as different socio-demographic groups.

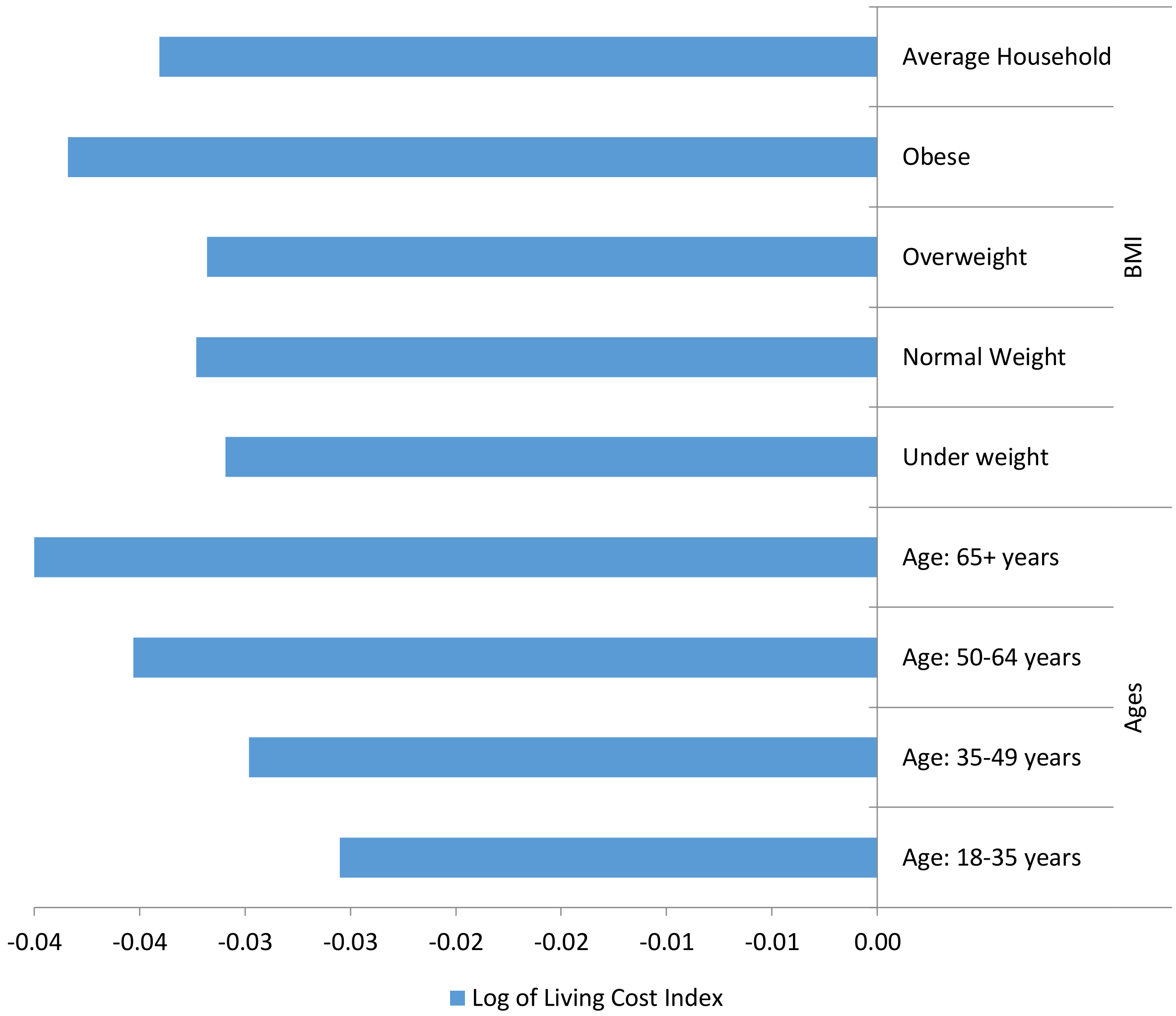

Figure 3-6 Expenditure savings due to the tax policy

3.4 Conclusion

Current regulations in Spain have not proven to be very effective in reducing the prevalence of overweight and obesity despite the high public cost it generates. Obesity and overweight are predominantly caused by high intake of dietary sugar and fat. As a result, some researchers and health policy advocates have begun to demand market intervention policies to tackle unhealthy dietary habits related to sugar and saturated fat intake. As such, the aim of this paper was to assess the potential effectiveness of internalizing the damage cost of obesity through a VAT reform (fat tax scheme) in Spain on food consumption and nutrient intake. Distributional effects on age and BMI of household heads were also considered.

To achieve this objective, we modified the VAT of food products to include a tax rate that internalizes the direct and indirect public health cost associated with diseases related to overweight and obesity. We assumed a revenue-neutral scenario; that is, revenues from taxed products are used to subsidize healthier products taking into account the saturated fat content. The methodological framework was based on the demand analysis by estimating food demand and nutrient intake elasticities.

The results found in this paper suggest that the impact of a revenue-neutral fat tax could contribute to an improvement in the quality of diet, although not in the very short term. The improvements are marginal, but they do move in the right direction. In fact, the fat tax would contribute marginally to reducing the current imbalance in macronutrient ratios by effectively reducing (increasing) the lipids (carbohydrates) intake. Moreover, it would decrease the consumption of saturated fatty acid, sodium, and cholesterol. On the negative side, it would significantly decrease the poly-unsaturated fatty acid intake. This tradeoff suggests that, subsidies based on poly-unsaturated fat content of foods could suffice. Thus, global food consumption patterns should be addressed with global fiscal policies.

The distributional effects of the tax policy have been measured on the basis of positive (negative) changes in macro- and micro-nutrient intake that are beneficial (detrimental) to the health of population segments based on age and BMI. One interesting result from this paper is that the tax is more effective for persons with obesity and overweight. As a consequence, it is more effective in those age groups in which the prevalence of overweight and obesity is higher. Welfare analysis in this paper suggest that internalizing the damage cost of obesity does not impose any economic burden on consumers, rather, the revenue-neutral nature of the tax results in expenditure savings for all household segments.

Although this paper has aimed to contribute to the current policy discussion about the implementation of fiscal policies to improve the current health status of the population, we must note that the results should be interpreted with caution. First, although most of the relevant food categories are included, our dataset does not record household income and food-away-from-home expenditure; consequently, the results are based on conditional food-at-home demand elasticities. Finally, we have assumed a perfectly elastic supply curve, which could be relaxed in the future.

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CHAPTER 4
Linking Risk Attitudes, Time Preferences and Body Mass Index in Catalonia

4.1 Introduction

The World Health Organization (WHO) considers obesity to be the most important cause of chronic illness and an epidemic in the 21st century, given its impact on morbidity, quality of life, and healthcare expenditure (WHO, 2016). People who are overweight or obese make up about 39% and 23% of the adult population in Spain (Gutiérrez-Fisac et al., 2012). People with obesity are at risk of heart attack and diabetes and show highly decreased levels of both productivity and life expectancy (Allison et al., 1999; Colditz, 1992). Economically, soaring obesity rates have led to a significant increase in both direct medical costs and the indirect costs resulting from lost productivity (McGinnis and Foege, 1993; Sturm, 2002; Wolf and Colditz, 1998).

Several socioeconomic factors have been found to play a major role in the high prevalence rate of obesity in Spain (Costa-Font and Gil, 2006). As a result, various socioeconomic policies have been targeted at obese people or people with a high risk of becoming obese. However, obesity is projected to increase in the coming years (OECD, 2017). As a result, some studies have suggested that obesity should be looked at from the context of individuals' propensity to become addicted to the consumption of certain foods (Cawley, 1999). Addiction to unhealthy behaviours, such as alcohol, drugs, and smoking, are usually explained by the rational addiction model of Becker and Murphy (1988). From the rational addiction context, obese individuals value the benefit from current consumption more than the present value of future health implications that result from overeating. The study of the interdependencies between the rate of time preferences, the coefficient of risk aversion, and an addiction to unhealthy behaviours, such as smoking, drinking, and unhealthy eating, has become popular (Ida and Goto, 2009).

Therefore, researchers have hypothesized that higher time discount rates could explain why some people are more likely to have unhealthy diets and respond unsuccessfully to interventions aimed at encouraging dietary change (Leitch et al., 2013; Rollins et al., 2010). Impatient people may disregard the long-term effects of fat and sugar consumption and invest in less healhty foods rather than in nutrient-rich foods. Previous studies have found that the extent of time discounting varies considerably among persons (Fishburn and Rubinstein, 1982; Frederick et al., 2002; Thaler and Shefrin, 1981), tending to be higher among younger persons (Reimers et al., 2009; Steinberg et al., 2009), individuals with lower socioeconomic status (Reimers et al., 2009), less-educated persons (Jaroni et al., 2004; Lee et al., 2013), and those with a higher risk of obesity (McLaren, 2007).

Aside from time discounting, people's risk preferences (risk aversion and loss aversion) have a predominant effect on their consumption decisions. Past literature has shown that individuals' struggles to maintain a healthy diet might be due to the existence of the phenomenon of loss aversion in consumption decision making. Loss aversion strongly influences the tendency for people to base decisions on movements away from a current state rather than on the final outcome and to regard losses from that state more than gains (Kahneman et al., 1991; Tversky and Kahneman, 1992).

Psychological factors, such as risk and time preferences, have a major influence on how individuals make food choices. In summary, the literature supports that obese and overweight persons are less risk averse or more loss averse (Anderson and Mellor, 2008; de Oliveira et al., 2016; Davis et al., 2010) and exhibit higher time preference rates (Borghans and Golsteyn, 2006; Komlos et al., 2004; Smith et al., 2005).

However, with the exception of de Oliveira et al. (2016), all other studies did a partial analysis by correlating either the risk attitudes or the time preferences of respondents with their body mass index. Following de Oliveira et al. (2016), we also performed a complete analysis by investigating the role that both risk and time preferences play in the tendency to become obese. However, the study of de Oliveira et al., (2016) had some limitations that cannot be ignored: 1) because their subjects were from low educational background, a visual multiple price list of Eckel and Grossman (2008) was used to elicit both risk and time preferences which does not take into account subjects' attitude toward losses, 2) they could not estimate all prospect theory parameters (risk aversion, loss aversion, and probability weighting) making their analysis incomplete, and 3) the method used to estimate the discount rate does not indicate whether subjects exhibit hyperbolic, quasi-hyperbolic or exponential time discounting behaviour.

We have improved on these limitations by using the incentivised double multiple price list (MPL) approach of Tanaka et al. (2010) to estimate both prospect theory parameters (risk, loss aversion, and probability weighting) time preference parameters (discount rate, present bias, and hyperbolicity) of consumers. The double MPL has been used in other fields to elicit both risk and time preferences without any empirical difficulty. For instance, Anderson and Mellor (2008) and Tanaka et al. (2010) used the double MPL to estimate the risk and time preferences of the Danish adult population and Vietnamese rice farmers, respectively. This is the first application on consumers to investigate how risk and time preference parameters correlate with body mass index. Specifically, 1) we estimated all three prospect theory and time preference parameters, 2) we compared the performance of the hyperbolic, quasi-hyperbolic and exponential time discounting models to select the model that best fit our experimental data, and 3) we controlled for a variety of individual covariates, including marital status, education, age, and income, that have been shown to be drivers of obesity.

The remainder of this article is structured as follows: section 2 provides a brief literature review on risk and time preferences. Section 3 discusses the sampling technique, experimental design, and the empirical methods used to derive our risk- and time-preference parameters. Section 4 presents and discusses the main results. The paper ends with some concluding remarks and limitations in section 5.

4.2 Conceptual Framework and Literature Review

Risk Preferences

The expected utility (EU) theory has long been the standard approach in behavioural economics modelling. Based on this framework, several methods have been developed to estimate the concavity of the utility function, such as the Balloon Analogue Risk Task (BART), the Eckel and Grossman method, the Domain-Specific Risk-Taking (DOSPERT) scale, or the Multiple Price Lists, among the most relevant.

The Balloon Analogue Risk Task (BART) (Lejuez et al., 2002) presents subjects with a sequence of choices of whether or not to gain additional money by pumping more air into a balloon, with each pump coming with the risk of losing the accumulated gains if the balloon pops. BART has been used to study risk attitudes across a variety of subfields, such as neuroscience (Fecteau et al., 2007), drug addiction (Bornovalova et al., 2005), and psychopathology (Hunt et al., 2005), However, it is not clear if this method, initially designed for analysing financial risk behaviour could be extended to other domains. In addition, BART requires a computer and multiple implementation trials, making it time consuming and inapplicable when there are no computers.

In the Eckel and Grossman method (Eckel and Grossman, 2008), participants are presented with a number of gambling games and are asked to choose one that they would like to play.

This method has been used by Reynaud and Couture (2012) and Dave et al. (2010). Even though this method produces significantly less noisy estimates of risk preferences, compared to BART, it does not allow the researcher to differentiate between different degrees of risk-seeking behaviour.

The Domain-Specific Risk-Taking (DOSPERT) scale developed by Weber et al. (2002) elicitates risk parameters through a questionnaire. DOSPERT relies on the individual's self-reported propensity for risk. The scale contains 40 items: eight items in the domains of recreation, health, social, and ethical risks and four items in the domains of gambling and investment. DOSPERT has been applied by Hanoch et al. (2006) to elicit the domain-specific nature of risk preferences. Despite the simple nature of the DOSPERT method, Charness et al. (2013) argue that the elicited risk preferences may not reflect an individual's true attitudes toward risk in each domain since the technique is not incentivized.

Holt and Laury (2002) popularized the use of the Multiple Price List lottery to estimate the concavity of the individual's utility function. The MPL has become very popular and has been widely used by researchers to compare risk attitudes across a wide array of contexts and environments (Anderson and Mellor, 2008). However, as in the previous methods based on the expected utility framework, it only allows researchers to estimate the concavity of the utility function.

Prospect theory (PT) (Kahneman and Tversky,1979) and the mental accounting framework (Thaler, 1980) have become very relevant in recent literature on behavioural economics (Harrison et al., 2010; Liu and Huang, 2013; Tanaka et al., 2010). PT postulates that risk preferences are not solely based on the concavity of the utility function but also on probability weighting and individuals' aversion to losses. Integration of loss aversion and probability weighing into individual preferences has enabled the prospect theory to explain a wide variety of economic phenomena that were considered puzzles from the expected utility point of view (Nguyen and Leung, 2009). Tanaka et al. (2010), following the Holt and Laury's Multiple Price List lottery, proposed the double Multiple Price List (MPL) lottery to allow for the estimation of the three prospect theory parameters: risk aversion, loss aversion, and probability weighting. They applied it to elicit the risk preferences of Vietnamese farmers, assuming a constant absolute risk aversion (CARA) utility function that was separable and stationary across time.

The double MPL was initially criticized on the basis that respondents might not understand the lottery, which could reduce the reliability of the results. In addition, participants might make inconsistent decisions by switching more than once. However, Anderson and Galinsky (2006) and Tanaka et al. (2010) dealt with these limitations by imposing strict monotonicity on revealed preferences and enforced transitivity. Several studies in the past have tried to establish a relationship between obesity and risk attitudes, such as de Oliveira et al. (2016), Borghans and Golsteyn (2006), Komlos et al. (2004), and Smith et al. (2005). However, none of these studies used the double MPL lottery, which is one of the main novelties of this study.

Time Preferences

Delay discounting can be defined as the extent to which people discount rewards (e.g. money, food, weight loss, etc.) as a function of having to wait for it (Reynolds et al., 2004). A low time discount rate indicates that an individual is patient and has self-control; on the contrary, a high time discount rate indicates that the individual is impatient and puts more emphasis on current gains over future rewards. Policies, especially fiscal policies, addressing obesity-related problems and its determinants, are likely to be flawed if there is a strong relationship between the rate of time preference and the propensity to become obese. Interventions need to factor these behavioural patterns into policy development and implementation.

Measurement approaches to discount rates vary due to: i) how surveys are administered; ii) the technique by which the discount rate is to be estimated; and (iii) whether rewards are real or hypothetical monetary choices. Surveys are usually administered in two ways: i) by questionnaire or ii) by a computerized method. Discount rates and present bias parameters are usually estimated by fitting an exponential discounting model (Kirby and Maraković, 1995; Myerson and Green, 1995), a hyperbolic model (Kahneman and Tversky, 1979; Mazur, 1987; Thaler and Shefrin, 1981), or a quasi-hyperbolic discount method (Benhabib et al., 2010). Hyperbolic and exponential discount models only measure the discount rate of money, while the quasi-hyperbolic discount model measures both the discount rate and present bias. The literature supports that exponential discounting performs poorly in the presence of experimental data (Frederick et al., 2002). As such, Laibson (1997) proposed a quasi-hyperbolic discounting model that performs better with field data. Moreover, previous literature supports that individuals are present bias and have high affinity toward high discount rates.

Tanaka et al. (2010) suggested a general time-preference model based on Benhabib et al's. (2010) experimental approach that is able to estimate three time-preference parameters: discount rates, present bias, and hyperbolicity. Moreover, their model also allows for comparing its performance in relation to the exponential, hyperbolic, and quasi-hyperbolic models mentioned above.

The literature also provides a few studies that have tried to relate time preferences to unhealthy behaviours (Appelhans et al., 2012; Leitch et al., 2013; Rollins et al., 2010), all of them supporting the existence of a strong relationship using different functional forms to estimate the discount parameter. This study is the first attempt to analyse the relationship between BMI and time preferences by adopting a flexible functional form, allowing us to jointly consider discount rates, present bias, and hyperbolicity.

4.3 Methodological framework

The sample

Our sample comprised 180 respondents from the Metropolitan Area of Barcelona (Spain). The sample was stratified taking into account the 2012 distribution of the population by BMI and age from the National Health Survey. Survey participants signed a letter of confidentiality before the start of the experiment and were paid 30 euros for completing the survey. Each participant completed the entire questionnaire in an average of 60–75 minutes. Out of the 180 respondents who completed the questionnaire, seven submitted incomplete questionnaires and were, therefore, discarded. Each survey covered detailed information on individual characteristics and participants' choices for risk- and time-preferences games. Respondents were asked to state their body mass index, which was validated after the experiment. The weight and height of the respondents were validated by trained personnel using a calibrated digital scale and stadiometer, respectively. BMI was calculated using the standard formula: kg/m^2. Participants were categorized into three groups: underweight[29] and normal weight group (<24.9); overweight group (25–29.9); and obesity group (>30.0) based on WHO criteria.

2.1 Risk Preferences

Under the PT, the individual's utility function can be expressed as follows:

$$PT(x, y; p) = pv(x) + (1 - p)v(y) \tag{1}$$

$$\text{where } v(x) = \begin{cases} x^{\sigma} & for\ x \geq 0 \\ -\lambda(-x^{\sigma}) & for\ x < 0 \end{cases} \tag{2}$$

$$\text{and } w(p) = exp[-(-\ln p)^{\gamma}] \tag{3}$$

[29] The underweight and normal weight categories were combined due to the lower number of participants (2% of the sample) falling into the underweight category.

$PT(x, y; p)$ is the expected prospect value over binary prospects consisting of the outcome (x, y) with the corresponding probability $(p, 1 - p)$. In our experiment, $(x, y; p)$ was specified for plan A and plan B in all scenarios. Note that the value function $v(x)$ should be estimated with x^{σ} for $x > 0$ or $-\lambda(-x^{\sigma})$ for $x < 0$. The parameter σ represents the concavity of the value function (risk aversion)—high values indicate respondents are risk loving; λ represents the degree of loss aversion—high values indicating respondents are more loss averse; and γ is a proxy for the nonlinear probability weighting.

Experiment Design

To elicit the three PT parameters (σ, λ, and γ), respondents were given three series of games that contained 35 pair-wise choices. Appendix 4A shows the three series of games. Series 1 consists of 14 games. Series 2 consists of 14 games, and Series 3 consists of seven games. In each game, the respondent is offered two plans: plan A and plan B. For instance, in series 1, the first game shows that plan A offers 30% chance of receiving 4 euros and 70% chance of receiving 1 euro, while plan B offers 10% chance of receiving 6.8 euros and 90% chance of receiving 0.5 euros. Since there are 14 games, each respondent has to decide whether he or she prefers plan A or plan B for each row[30].

Following Tanaka et al. (2010), monotonicity was imposed on the respondents' choice decisions, indicating that if respondent *i* switchs at row q for series 1, we conclude that he/she prefers plan A over plan B at row q-1 and prefers plan B over plan A at row q. Thus, each respondent had three options: a) choose plan A throughout all games; b) choose plan B throughout all games; and c) choose plan A for a certain number of games and then switch to plan B for the rest. Individuals who are more averse to loss would choose plan A a greater number of times over plan B. Series 2 followed the same procedure as in series 1. The loss-aversion parameter is calculated using series 3. Contrary to the previous two series, payoffs in this series were either positive or negative.

After the respondent completed the experiment, two bingo cages were used to determine the money that each respondent took home. The first bingo cage contained 35 numbered balls (indicating which row/question to play), while the second contained 10 numbered balls (indicating the probability). If ball number 10 was randomly selected from the first bingo cage, this meant that the subject would play row/question 10 out of the 35 questions. Once the question has been determined, a ball would be drawn from the 10 numbered balls in the second bingo and the selected question was played according to the subject's plan. For instance, if the

[30] The maximum amount offered in Plan B was 170€, equivalent to the regulated minimum salary for one week.

subject drew the ball number 2 from the second bingo and had previously chosen plan A, he or she would have earned 4 Euro (or 0.5 Euro if the respondent had chosen plan B).

Calculating risk parameters

The switching points from series 1 and series 2 are used to estimate the curvature of the utility function (risk aversion) and the nonlinear probability-weighting parameter of each participant. Calculated parameter estimates[31] of risk aversion and probability weighting for different combinations of the switching points in series 1 and series 2 are shown in Table 4-1and Table 4-2, respectively. For instance, from **Error! Reference source not found.**, if the respondent switched at game 5 in series 1 and game 3 in series 2, then the corresponding risk aversion parameter is 1.0, indicating risk neutral. Also, for the probability-weighting parameter, if the respondent switched at game 5 in series 1 and game 3 in series 2, then the corresponding risk aversion parameter is 0.8, indicating overweighting of low probabilities.

After obtaining the risk-aversion and probability-weighting parameters from both series 1 and series 2, we can estimate the loss-aversion parameter using the switching points in series 3. This was achieved by writing out an inequality for the switiching points of series 3 and introducing the risk parameter into the equation 1 (see Liu and Huang, 2013)

[31]Example when a respondent switch from plan A to B at the fifth question in series 1 and at the third question in series 2, the following inequalities should hold. Average estimates are shown in Table 4-1and Table 4-2.
$4^{\sigma}\exp[-(-\ln.3)^{\alpha}]+1^{\sigma}\exp[-(-\ln.7)^{\alpha}]>9.3^{\sigma}\exp[-(-\ln.1)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln.9)^{\alpha}]$,
$4^{\sigma}\exp[-(-\ln.3)^{\alpha}]+1^{\sigma}\exp[-(-\ln.7)^{\alpha}]<10.6^{\sigma}\exp[-(-\ln.1)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln.9)^{\alpha}]$,
$4^{\sigma}\exp[-(-\ln.9)^{\alpha}]+3^{\sigma}\exp[-(-\ln.1)^{\alpha}]>5.6^{\sigma}\exp[-(-\ln.7)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln.3)^{\alpha}]$,
$4^{\sigma}\exp[-(-\ln.9)^{\alpha}]+3^{\sigma}\exp[-(-\ln.1)^{\alpha}]<5.8^{\sigma}\exp[-(-\ln.7)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln.3)^{\alpha}]$.

Table 4-1 Switching point (question) in Series 1 and 2, and approximations of σ (parameter for the curvature of power value function/risk parameter)

σ	**Switching point for series 1**													
Series 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Never
1	1.50	1.40	1.35	1.25	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.65	0.55	0.50
2	1.40	1.30	1.25	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.60	0.55	0.50
3	1.30	1.20	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45
4	1.20	1.15	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45	0.40
5	1.15	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45	0.40	0.35
6	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35
7	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30
8	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25
9	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20
10	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.20
11	0.80	0.70	0.65	0.60	0.65	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.15
12	0.75	0.65	0.60	0.55	0.50	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.20	0.15	0.10
13	0.65	0.60	0.55	0.50	0.45	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.15	0.10	0.10
14	0.60	0.55	0.50	0.45	0.40	0.35	0.35	0.30	0.25	0.20	0.15	0.10	0.10	0.10	0.05
Never	0.50	0.45	0.40	0.40	0.35	0.30	0.30	0.25	0.20	0.15	0.10	0.10	0.05	0.05	0.05

Table 4-2 Switching point (question) in Series 1 and 2, and α (probability sensitivity parameter in Prelec's weighting function)

α	Switching question in series 1														
Series 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Never
1	0.60	0.75	0.75	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.40	1.45
2	0.60	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.35	1.40
3	0.55	0.60	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30
4	0.50	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25
5	0.45	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20
6	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15
7	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10
8	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05
9	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
10	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
11	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
12	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
13	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
14	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
Never	0.05	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.45	0.55	0.55	0.65	0.60

Time Preferences

Following Benhabib et al. (2004) and Tanaka et al. (2010), we have estimated a general time-preference model that nested other models that have been traditionally used in the literature to elicit time preferences: exponential, hyperbolic, and quasi-hyperbolic discounting. Under the general framework, the present value of income, y, at time t>0 adopts the following expression:

$$y\beta(1-(1-\theta)rt)^{1/(1-\theta)} \tag{4}$$

where r, β, and θ are the time discounting, present bias, and hyperbolicity parameters of the time preference function. If $\beta = 1$, as θ approaches 1, then the discounted value of y reduces to exponential discounting (e^{-rt}) in the limit. However, if $\beta = 1$, when $\theta = 2$, the discounted value reduces to a hyperbolic discounting model (1/(1+rt)). In the same way, if $\theta = 1$ (in the limit) and β is free, the discounted value reduces to a quasi-hyperbolic discounting model (βe^{-rt}). These restrictions imposed on the general model allow us to estimate and compare four time discounting models.

Experiment Design

The basic experimental design for eliciting individual discount rates and present bias follows the approach of Tanaka et al. (2010). The experiment started by reading the following instruction to participants: "In this game, you will receive money either today or sometime in the future, depending on the choices you make. There are 75 games (Appendix B). In each game, we will offer you two plans: plan A or plan B. We would like you to choose either plan A or plan B for each question." The experiment lasted about 35 minutes. A trusted agent[32] was chosen who would keep the money until the delayed delivery date to ensure subjects believed the money would be delivered. The agents were instructed to deliver the money to the respondent, which tried to equalize the pure transaction costs of receiving money immediately (i.e. at the end of the experiment) or in the future. In the latter case, the participant placed the money into an envelope, sealed it, and wrote his (her) name and the date of delivery on the envelope. All envelopes were given to the trusted agency.

After the instruction, each respondent in our experiment was given payoff tables as shown in appendix B to elicit their discount rates for money and present bias. Each payoff matrix gives the respondent the choice to choose between plan A, corresponding to an amount *y* euro over a period of 3 days to 3 months, and plan B to earn an amount *x* today. Whilst the amount earned

[32] In this study, the trusted agent was the recruitment company, as normally citizens participating in our experiment are recruited between 8 to 12 times during the year, by this company, to participate in other experiments.

in option A remains constant, the amount earned increases in option B as the respondent moves down the five games in each of the 15 series considered. As in the previous experiment, to determine the amount of money the respondent took home and when, a bingo cage containing 75 numbered balls was used. At the end of the experiment, each respondent was asked to draw one ball to determine which game would be played for real money. The amount earned varied between 0.5 euros and 30 euros. As an example, from appendix B, suppose that the i-th respondent drew ball 21. If he or she had chosen plan A, then he/she would be paid 30 euros in 1 month (the money was placed in an envelope, was closed and signed by the respondent, and delivered to the trusted agent). However, if he/she had chosen plan B, then he/she received 5 euros on the same day of the experiment.

The probability that respondent *i* will choose an immediate reward *x* over the delayed reward *y* in *t* days by P(x>(y,t)) was described by the logistic function:

$$P(x > (y,t)) \frac{1}{1+\exp(-\mu(x-y)\beta(1-(1-\theta)rt)^{1/1-\theta}))} \tag{5}$$

The time-preference parameters r, β, and θ are recovered from the logistic regression function, where μ is the noise coefficient.

4.4 Results

Some Preliminary Results

The main household characteristics of the sample used in this paper are shown in Table 4-3. About 69% of the respondents in our dataset were married, the remaining being single, divorced, or widowed. More than 90% of the respondents had more than a basic education: trained professionals or secondary school or university graduates. About 32% of the respondents earned the average salary in the Metropolitan Area of Barcelona (Spain) with the rest earning more than the average salary. The average weight and height in our sample were 69.88 kg and 1.66 meters, respectively, leading an average BMI of 25.36 kg/m^2

The BMI distribution among the sample is shown in Figure 4-1 and Figure 4-2. The distribution was skewed to the right, indicating that the majority of the respondents had a BMI greater than the 25 kg/m^2. Only one respondent had a BMI greater than 40 kg/m^2. Overweight and obese people represented 37.8 and 10.9 percent of the sample, respectively. These figures are close to those estimated for the Barcelona population in 2012 by the Public Health Department[33] (35.2% of the populace were overweight and 13.8% were obese).

[33] https://www.diba.cat/es/web/entorn-urba-i-salut/sobrepes-i-obesitat

Table 4-3 Household characteristic (%)

Variables	Mean	Std. Error	[95% Conf.	Interval]
Probability Weighting	0.64	0.03	0.59	0.69
Risk Aversion Coefficient	0.58	0.03	0.52	0.63
Loss Aversion Coefficient	3.67	0.30	3.09	4.26
Married	0.69	0.04	0.62	0.76
Age	46.38	1.11	44.20	48.57
Basic Education	0.08	0.02	0.04	0.12
Income Less 1500	0.32	0.04	0.25	0.39
Income Between 1500 And 2500	0.42	0.04	0.34	0.49
Income Between 2500 And 4000	0.19	0.03	0.13	0.25
BMI	25.36	0.32	24.53	25.80
Body Weight	69.88	1.12	67.67	72.09
Body Height	1.66	0.01	1.65	1.68

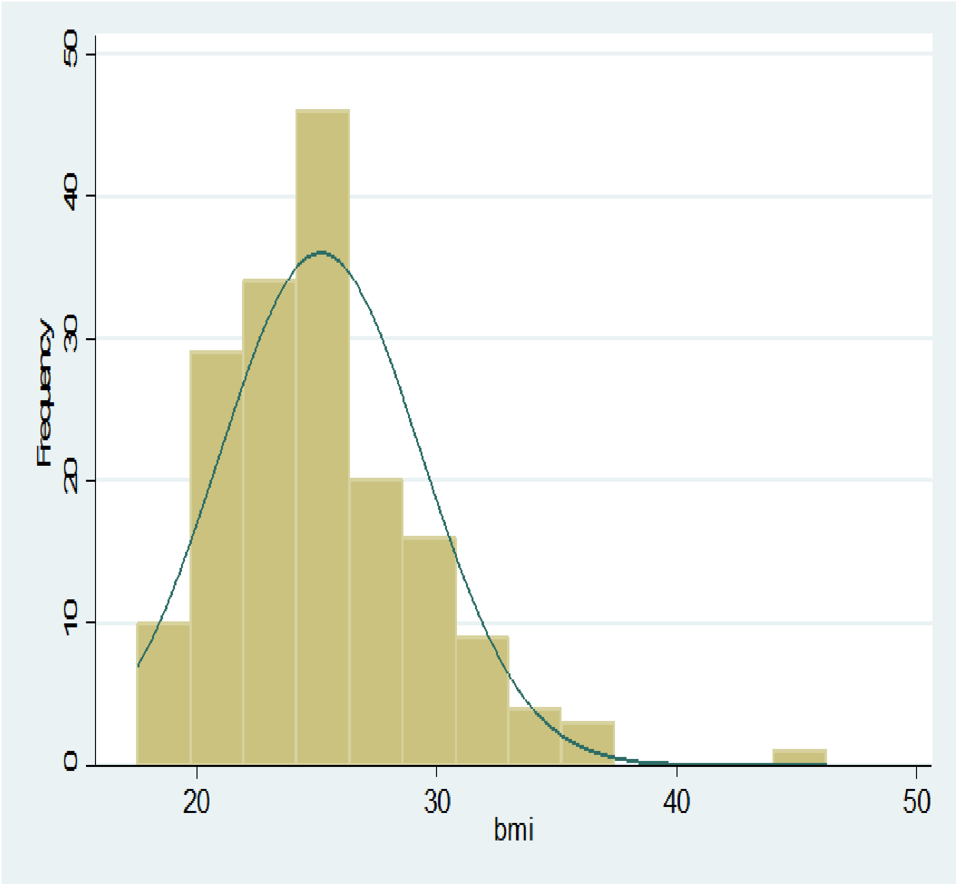

Figure 4-1 Normal and frequency distribution by BMI

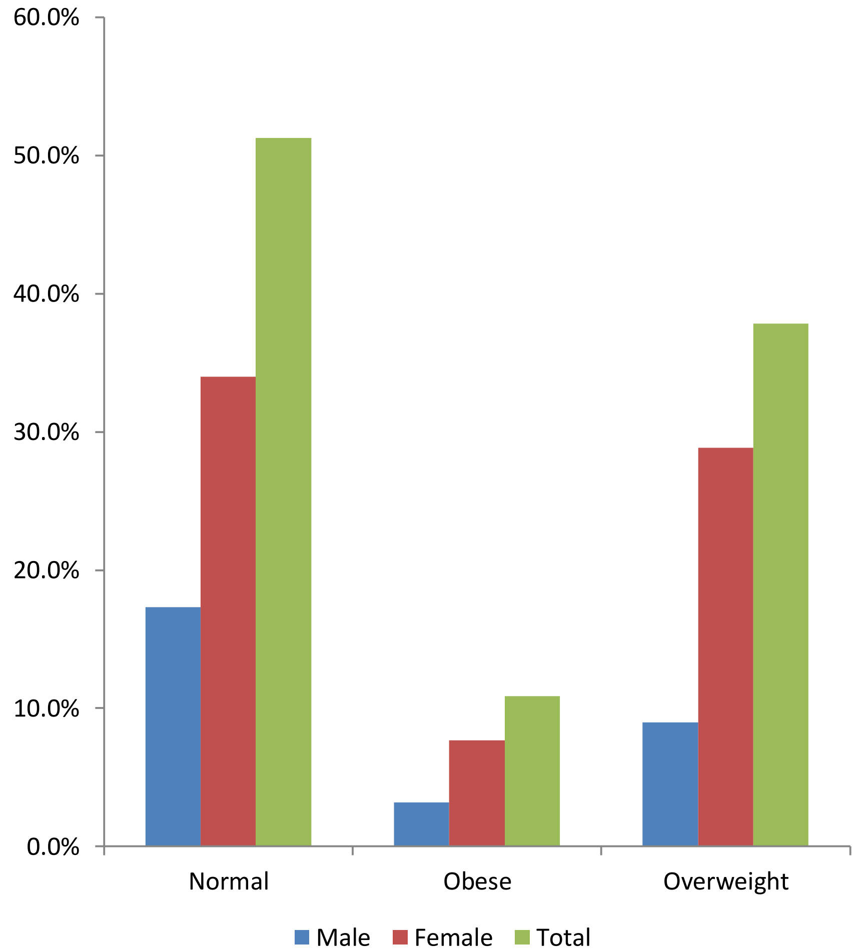

Figure 4-2 Distribution of respondents by BMI

In relation to risk attitudes, Table 4-4 shows the average number of choices made by respondents in series 1 and 2 (see Appendix 4A). The numbers in the first column and row correspond to the switching points in series 1 and 2. The frequency numbers in the table represent the number of subjects who switched at that particular combination of switching points in series 1 and 2. The bolded figures correspond to the number of respondents whose choices would correspond to those predicted by the expected utility. As can be observed, for this particular experiment, the results indicate that the majority of the respondents made their choices outside the expected utility (EU) theory.

Table 4-4 Distribution of Switching Points in Series 1 and Series 2

		Series 1											
	Switching Points	**Never**	**1**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Never	6	10		2	2	3	4	3	3	3	1	1
	1	6	10		1	3	**2**	3	2	2	3	2	1
	3		1	1								1	
	4	1	1	**1**	1				1	2			
	5		1			1							
	6					2		1					
	7				1	1		2		1	1		
Series 2	**8**	1	3	1		3	2		4				1
	9		1		1	1	4	2	1		1		
	10	1			1	2		3	4				
	11						1	1	1				
	12	1	1		3	1	1	3	1		1	1	1
	13				1							2	
	14						1				1	2	1

The calculated propsect theory parameters are shown in Table 4-5. The average risk-aversion parameter was 0.588, indicating that, on average, respondents are risk averse. The average loss-aversion parameter is 3.67, which also indicates that, globally, respondents are loss averse. The average of the nonlinear probability-weighting parameter is 0.69 (less than 1), meaning that the majority of the respondents have a tendency to overweigh low probabilities. According to TCN, if γ =1 and $\lambda = 1$, then the utility function reduces to the EU function. We strongly reject this hypothesis in our experiment, indicating that PT is the adequate framework to analyse risk preferences within our sample. In addition to the calculated sample averages, Figure 4-3 and Figure 4-4 show the normal distribution of the risk-aversion and loss-aversion coefficients among participants, respectively. The distribution of the risk-aversion coefficient shows an affinity toward lower risk since the majority of the respondents are found on the left side of the normal distribution. In relation to loss aversion, Figure 4-4 does not support the absence of loss aversion since the coefficient is above 0. Most respondents have a loss-aversion coefficient between 0.06 and 11.79; larger loss-aversion coefficients indicate a higher aversion to losses.

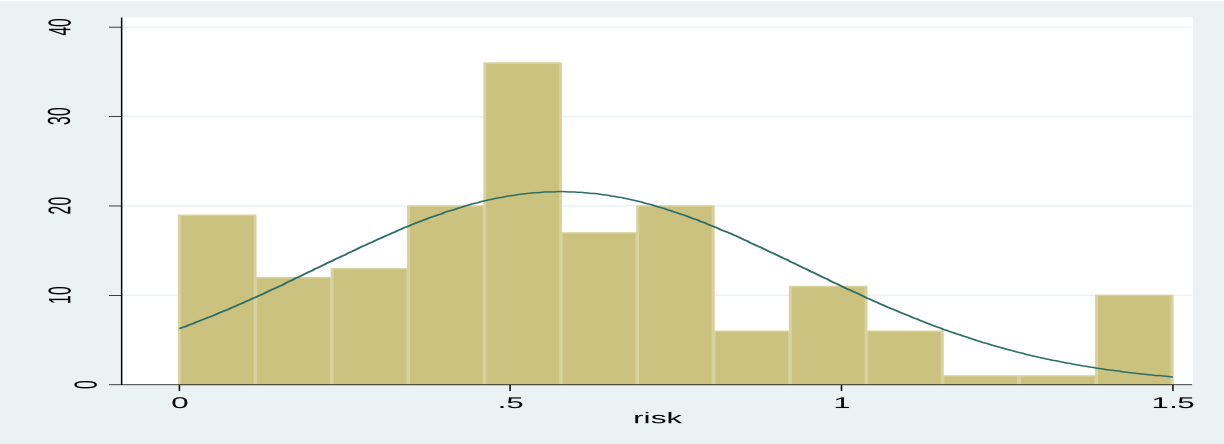

Figure 4-3 Normal and Frequency Distribution by Risk Aversion Coefficient

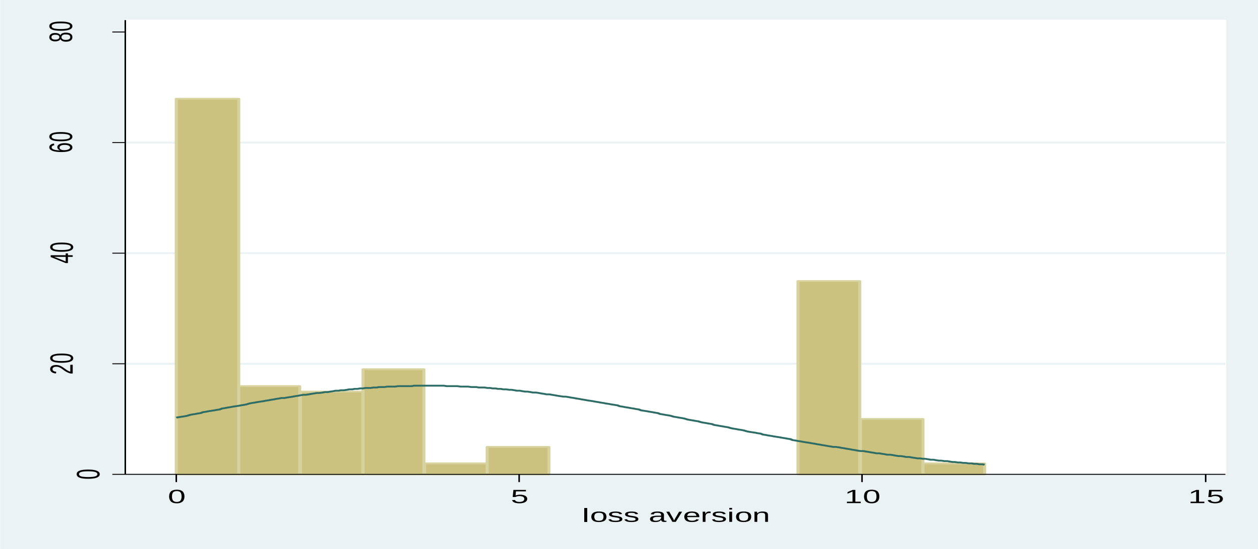

Figure 4-4 Normal and frequency distribution of loss aversion

Table 4-5 Risk Preference Parameters

Variables	Mean	Std. Error	[95% Conf.	Interval]
Probability Weighting	0.64	0.03	0.59	0.69
Risk Aversion Coefficient	0.58	0.03	0.52	0.63
Loss Aversion Coefficient	3.67	0.30	3.09	4.26

Risk Preferences and Body Mass Index

To analyse the relationship between risk preferences and BMI, we estimated, by ordinary least squares, three regressions of the curvature of the utility function (σ), the loss aversion parameter (λ), and probability-weighting parameter (γ) against BMI, while controlling for socioeconomic characteristics. Robust standard errors are reported for all three equations in

Table 4-6. As can be observed, we have found a significant positive relationship between risk aversion and BMI indicating that less risk averse persons have a higher propensity to develop higher BMI. This result is consistent with previous studies by Anderson and Mellor (2008) and de Oliveira et al. (2016). This results also confirms the rational addiction theory, which postulate that less risk averse individuals are willing to take the risk of eating unhealthy foods despite the negative health consequences. No significant relationship was found between loss aversion and probability weighting and BMI. This means that even though obese people are less risk averse, the propensity to become obese is independent of subjects' aversion to loss.

Some control covariates had significant relationships with the curvature of the utility function (σ), the loss-aversion parameter (λ), and the probability-weighting parameter (γ). The strongest effects suggest older subjects were more risk averse, while lower income subjects were less risk-averse. These results confirm hypothetical studies that found older adults to be more risk averse (Botwinick and Thompson, 1966; Kogan and Wallach, 1961). The relationship between income and risk tend to contradict previous studies that found that risk aversion reduces some as income increases (Barsky et al., 1997; Donkers et al., 2001). Studies like Levin et al. (1988)

found that women are more risk averse than men. However, we did not find any significant results.

Table 4-6 Correlations with determinants of Risk aversion, Loss aversion and probability sensitivity parameter in Prelec's weighting function

Explanatory Variables	Risk aversion	Loss aversion	Probability weighting
Body Mass Index	0.014 (-0.008)*	0.000 (0.082)	0.002 (0.007)
Age	-0.003 (-0.002)**	0.057 (0.017)***	0.000 (0.002)
Married =1	0.023 (-0.063)	0.995 (0.711)	0.023 (0.066)
Gender (Female=1)	-0.103 (-0.065)	-0.660 (0.717)	-0.087 (0.060)
Education(Basic =1)	0.110 (-0.119)	0.574 (1.237)	-0.189 (0.098)*
Income (Less 1500 =1)	0.111 (-0.056)**	0.409 (0.713)	0.078 (0.064)
Constant	0.399 (-0.207)*	0.562 (2.108)	0.622 (0.194)***

*,**,*** respresent significant at 10%, 5%, 1%, respectively.

Time Preferences and Body Mass Index

A significant share of previous literature that tried to elicit individual time preferences was based on the estimation of an exponential discounting model. However, this model has often been rejected by experimental and field data (Frederick et al., 2002). The results in Table 4-7 show that we have estimated four time-preference models, with equations 1–3 being nested in equation 4 based on restrictions imposed on beta *(β)* and/or theta *(θ)*. The statistical performance, in terms of the R^2, improves from equation 1 to equation 3. This suggests that the quasi-hyperbolic and the general model with unrestricted beta and theta are superior to the exponential and hyperbolic models. The advantage of the quasi-hyperbolic model over both the exponential and hyperbolic model is that, with beta being unrestricted, the quasi-hyperbolic model allows the estimation of both present bias and discount rate. Similarly, the general model goes further to estimate hyperbolicity *(θ)* of the preference model (see Tanaka et al., 2010). From the general model, the parameters for discount rate, present bias, and hyperbolicity are 0.006, 0.82, and 3.513, respectively. This implies that our respondents should trade 78.99 euros today for 100 euros in a week and 71.27 today for 100 euros in one month. However, estimating the general model with unrestricted θ does not improve R^2 compared with the estimation of the quasi-hyperbolic model, so we only focused our attention on the quasi-hyperbolic discounting.

Table 4-7 Comparison of Exponential, Hyperbolic, and Quasi-Hyperbolic Discounting Models

choice	Exponential	Hyperbolic	Quasi-hyperbolic	Equation (1)
Meu	0.093***	0.093***	0.119***	0.119***
Rate	0.009***	0.009***	0.004***	0.006***
Beta			0.800***	0.816***
Theta				3.513***
Adjusted R-Squared	0.5217	0.5231	0.5278	0.5278

*** represent 1% significant. p-values derived from robust standard errors

To identify the relationship between the time preference and subjects' demographic covariates, we introduced BMI and control covariates into the quasi-hyperbolic time-preference model. The quasi-hyperbolic time-preference parameters were derived using the logistic model described below:

$$(x > (y,t))\frac{1}{1+\exp(-\mu(x-y\beta exp[rt]))} \qquad (6)$$

where $\beta = \beta_0 + \sum \beta_i X_i$, $r = r_0 + \sum r_i X_i$, X_i are demographic variables described above. β_i and r_i are the estimated coefficients associated with the X_i.

Estimated parameters from both equations are shown in As can be observed, BMI is positively correlated with impatience (higher discount rates). The implication is that people who are impatient have a tendency to develop higher BMI. This result is consistent with that from Borghans and Golsteyn (2006); Scharff (2009); Smith et al. (2005); Weller et al. (2008); and Zhang and Rashad (2008) who showed that impatience positively correlates with a higher BMI.

Table 4-8. As can be observed, BMI is positively correlated with impatience (higher discount rates). The implication is that people who are impatient have a tendency to develop higher BMI. This result is consistent with that from Borghans and Golsteyn (2006); Scharff (2009); Smith et al. (2005); Weller et al. (2008); and Zhang and Rashad (2008) who showed that impatience positively correlates with a higher BMI.

Table 4-8 Correlations with Present Bias and Discount Rates (OLS)

	Present Bias	**Discount Rate**
µ	0.130***	
Beta/Rate	1.064***	-0.007
Gender*BMI	0.011*	-0.033
Married	0.010	-0.167
Gender	-0.296*	0.967*
Age	-0.004	-0.0002
BMI	-0.006	0.038**
Primary	0.024	0.704**
Age square	0.00002**	0.00006

*Coefficients of discount rate are multiplied by 100. *,**,*** respresent significant at 10%, 5%, 1%, respectively.*

Among the socioeconomic covariates, people with only a primary education are more impatient as compared to people with a secondary and university education. Fuchs (1982), Huffman et al. (2017) and Tanaka et al. (2010) also found lower discount rates among highly educated people. This is plausible as people who drop out of school usually prefer to work and earn an income as soon as possible seeing the benefit of higher education as delaying the gratification from today's income. Finally, we have found that females are more impatient than males in the study area, while Dittrich and Leipold (2014) showed the contrary.

Present bias is significant at the 1% level, suggesting the existence of present bias among respondents. Tanaka et al. (2010) also found the existence of present bias among farmers in Vietnam. While Courtemanche et al. (2015) predicted that present bias increases with BMI, this study shows that present bias increases with BMI only among women.

4.5 Conclusions

Obesity in Spain is on the rise despite the numerous socio-political and socioeconomic policies that have been implemented during the past decades. The framework of rational addiction models the behaviour of individuals from the context of risk and time preferences. Therefore, many hypothetical studies have suggested a strong correlation between risk, time preferences, and obesity rates. However, no such empirical study has been carried out in Spain to ascertain whether such a relationship exists.

The aim of this study was to investigate and ascertain the relationship between risk attitudes, time preferences, and BMI in Spain. We used the experimental approach of Tanaka et al. based on the prospect theory framework to estimate three risk preference parameters: risk aversion, loss aversion, and probability weighting. Similarly, based on the experimental approach of Tanaka et al. and the empirical framework of Benhabib et al. 2007, we estimated four time-preference models (exponential, hyperbolic, quasi-hyperbolic, and the general model); in the quasi-hyperbolic model, we tested for the relationships between present bias and time discounting and obesity.

The experimental data shows the existence of risk aversion, aversion toward losses, and impatience among our respondents. BMI was significant and positively associated with risk aversion. In addition, impatience was found to be highly associated with people with a high BMI. Our results also confirm that risk and time preferences are independent of the methodological framework. No significant relationship exists between probability weighting, loss aversion, and present bias and BMI among our subjects.

Considering the importance of risk and time preferences on the development of obesity, economic policies should begin to factor such individual heterogeneity into economic policy instruments. For instance, policy recommendations that suggest taxes or fiscal policies can influence consumer behaviour leading to a reduction in obesity should consider psychological differences in demand modelling. In addition, the government should develop policies targeted at specific segments of the society instead of a one-for-all policy goal that yields little or no results.

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CHAPTER 5
Attitudinal, Behavioural and Socioeconomic Drivers of Obesity in Catalonia: A Multidimensional Model using Path Analysis

5.1 Introduction

Obesity can be defined as an unhealthy excess of body fat, which predisposes an individual to higher risk of medical illness and premature mortality (Garrow and others, 1988; Hruby and Hu, 2015). The generally accepted measure of obesity is weight per height squared, referred to as Body Mass Index (BMI) ("World Health Report Life in the 21st century A vision for all Report of the Director-General," 1998). In 2012, the total adult population in Spain who had 24.9>BMI<30 and BMI>30 were 39% and 23%, respectively (Gutiérrez-Fisac et al., 2012).

Evidence from developed countries suggest that the prevalence of obesity is increasing at exponential rates (Flegal et al., 2012). People with obesity are at risk of heart attack and diabetes and show high level of decreases in both productivity and life expectancy (Allison et al., 1999; Colditz, 1992). Economically, the high prevalence of obesity in most countries has led to significant increase in both direct medical costs and indirect costs from lost in productivity (McGinnis and Foege, 1993; Sturm, 2002; Wolf and Colditz, 1998).

Concern about the assumed causes of obesity has led to intervention programs in the line of: (1) promoting healthy eating, by focusing on reducing caloric intake; and (2) discouraging sedentary lifestyles by increasing physical activities, which is vital for the purpose of increasing energy expenditure (World Health Organization, 2009). In addition, recently, there is a proliferation of economic research on the causes of obesity and on approaches to prevent and reduce obesity.

Tackling obesity through healthy diet and physical exercise has not yielded any positive response. As a result, the causes of obesity are multifactorial (Cutler et al., 2003). The traditional believe that the causes of obesity are due to diet and physical activities need to be coupled with individual inherit characteristics such as risk attitudes, beliefs about obese persons (BAOP) or attitudes towards people with obesity (ATOP), psychological factors such as body image dissatisfaction/misperception and socioeconomic characteristics. Most studies have reviewed the association between obesity and some of these factors. However, simultaneous examination of the inter-relations among the factors by using a multilevel analysis has rarely been performed. Using structural equation modelling facilitates the simultaneous estimation of the inter-relations among fundamental factors that influence obesity.

Structural Equation Model (SEM) is a generalization of numerous statistical techniques, such as ANOVA, path modelling, linear regression and factor analysis. Path modelling allows researchers to empirically estimate the relationship between a group of endogenous and exogenous variables at the same time (Gunzler and Morris, 2015). While most SEM approaches are suitable for studies dealing with latent (unobserved) variables, path analysis aspect of SEM allows researchers to perform analyses with observed variables only (Kowalski and Tu, 2008). In the light of this, we model the casual links and interactions among the fundamental causes of obesity using experimental and household data from Catalonia.

Past studies either carryout a comprehensive literature review or empirical analysis that seeks to establishes the correlation between obesity and causative factors. This study improves past research by providing empirical estimates for the possible direction and strength of association that exist among the variables and obesity. Path coefficients and their significance show the extent to which the covariates of obesity are inter-related and influence the development of obesity. Secondly, we rely on household and experimental data instead past published works. This is because the identified relationships in literature have different geographical and methodological dimensions. Our analysis therefore shows the extent to which all the covariates affect a specific group in a specific geographic area. Third, this is the first study to carry out empirical review on the possible factors driving adult obesity in Catalonia.

The rest of the paper will be organised as follows: section 2 discusses the conceptual framework on the causal relationships among the causes of obesity found in literature. Section 3 describes the data and the structural model applied to our data. Section 4 and 5 present and discuss the results generated from our data. Section 6 provides summary and some concluding remarks.

5.2 Conceptual framework to explain obesity drivers

Socio-Economic Drivers

Socio-economic factors play a major role in the high prevalence rates of obesity in Spain (Costa-Font and Gil, 2006). The study of the relationship between income and obesity has provided mixed results. For instance, a strong positive relationship has been found between obesity/overweight and income (Mendez et al., 2004). On the contrary, some studies have found higher income (or education or social status) to be associated with lower risk of obesity (Costa-Font and Gil, 2008; Nayga Jr, 1999).

Studies linking obesity and marital status have also been inconclusive. For instance, literature has found married men and women to be more likely to be obese than unmarried ones in the US (Hayes and Ross, 1986; Schoenborn, 2004). A similar result was found in northern Canada (Young and Sevenhuysen, 1989). However, some studies did not find any significant relationship between marital status and obesity (Kittel et al., 1978). Gender differences in the prevalence of obesity has been shown to be very significant as women tend to have higher rates of obesity than men (Jones-Johnson et al., 2014).

A few studies have tried to explain the relationship between body mass index and age in relationship to osteoarthritis (Rai et al., 2013), Hyperglycaemia (Wakabayashi and Daimon, 2012) etc. However, there is no recorded study analysing the direct relationship between age and obesity.

Other drivers of the prevalence of obesity include: lower educational levels (Grossman, 2015), unhealthy lifestyles and dietary patterns (Peytremann-Bridevaux et al., 2007), better technologies (Lakdawalla and Philipson, 2002) and advertisement of foods low in nutrients but high in fats (Aktacs Arnas, 2006).

Consequently, based on our data, the following hypotheses will be tested:

H1. Income is positively related to BMI.

H2. Women are associated with higher BMI values.

H3. Married persons are associated with higher BMI values.

H4. Age is positively correlated with BMI.

Attitudes Towards Obesity People (ATOP) And Beliefs About Obesity People (BAOP)

The prevalence of negative attitudes towards people with obesity (low ATOP scores among the population) has increased by 66% over the past decade (Andreyeva et al., 2008; Puhl and Heuer, 2009). There is a school of thought that believes that weight stigmatization or negative attitudes towards people with obesity is a useful tool to motivate people with obesity to adopt healthier lifestyle behaviours (Hebl and Heatherton, 1998).

Literature has found significant and positive correlation between ATOP and BAOP scores (Crandall et al., 2001). Individuals who have positive attitudes towards obese people (high ATOP) believe that obesity cannot be controlled by them (high BAOP). For instance, Flint et al. found that more negative attitudes towards people with obesity were associated with a stronger belief that obesity is controllable in the UK (Flint and Snook, 2015).

The extent to which individuals demonstrate positive or negative attitudes towards obese people has been found to be mediated by some socioeconomic factors (Flynn and Fitzgibbon, 1998). Anti-fat attitudes have been found to be determined by individual characteristics including gender, age, frequency of exercise and body mass index (BMI) (Flint et al., 2015). Attitudes towards persons with obesity is also mediated by age, socioeconomic status and gender (Allison et al., 1991). However, no significant relationship between belief that obesity is controllable and socioeconomic factors has been found (Allison et al., 1991).

Therefore, the following hypotheses have been proposed:

H5. Positive attitudes towards obese people is positively associated with the belief that obesity is uncontrollable.

H6. Persons who belief obesity is controllable have a higher body mass index.

H7. Women will tend to exhibit more negative attitudes towards obese people.

H8. Persons with higher socioeconomic status (measured by income) exhibit weight stigma.

Body Image Dissatisfaction and Weight Perception

Body image is considered a multifaceted construct that involves an individual's perceptions, thoughts, feelings, and behaviours about the size, shape, and structure of his/her body (Bhatt-Poulose et al., 2016).There has been a rapid concern about body image over the years, and the prevalence of body image dissatisfaction (BID) has increased especially among adolescents (Mousa et al., 2010; Pinheiro and Giugliani, 2006). Consequently, individuals who are dissatisfied with their body are more likely to adopt behaviours that may place them at risk for more weight gain and poorer overall health (Bibiloni et al., 2013; Rodgers et al., 2016).

Higher socioeconomic status (income and education) correlate positively with body dissatisfaction (Wang et al., 2005). Among adolescents, body image dissatisfaction significantly depends on gender and weight status (Smolak, 2004) while no relationship between marital status and body image dissatisfaction has been found (Friedman et al., 1999). Body image dissatisfaction has been found to be strongly correlated with body weight control practices in both males and females (Furnham et al., 2002; Volkow et al., 2013). However, women are more likely to be dissatisfied with their body than men, which makes them to be on diet more frequently (Furnham and Calnan, 1998).

Taking this literature into account we postulate that:

H9. Persons with a higher BMI also exhibit a higher dissatisfaction with their bodies

H10. Persons with correct weight perception have a lower body mass index

H11. Persons with correct weight perception are also more satisfied with their body

H12. Body image dissatisfaction is positively associated to socioeconomic status.

H13. Body image dissatisfaction is positively associated with marriage.

H14. Persons who are on diet are more dissatisfied with their bodies.

Risk and Loss Aversion

Risk attitudes such as risk aversion and loss aversion has been found to influence how individuals make food choices. For instance, obese and overweight persons heve been found to be less risk averse (or more loss averse) (Anderson and Mellor, 2008; Davis et al., 2010). Risk and loss aversion also correlate with individual characteristics. Lower risk aversion tend to correlate with gender (men), self-employment, lower income and lower education status (Hartog et al., 2002). The relationship between risk aversion and gender is mixed (Eckel and Grossman, 2008; Moore and Eckel, 2003). In addition, risk aversion has been found to increase with age (Bakshi and Chen, 1994). Similarly, married people tend to be more risk averse than individuals living without partners, who are either divorced or never married (Sunden and Surette, 1998). A few studies have also suggested that loss aversion increases in age, income, and wealth, and decreases in socioeconomic status (i.e. education) (Gaechter et al., 2010).

Consequently, we hypothesize that:

H15. Risk aversion is negatively associated with body mass index.

H16. Risk aversion is negatively associated with loss aversion.

H17. Risk aversion increases with individual's age.

H18. Females are more risk averse than males.

H19. Risk aversion increases with socioeconomic status.

H20. Loss aversion increases with age

H21. Loss aversion increases with socioeconomic status or income

Each section is concluded with hypotheses suggesting the causal relationships that exist among the factors shown in **Figure 5-1**. **Figure 5-1** depicts the path analysis model that is tested here. The figure shows that, according to our framework weight perception, body image dissatisfaction, belief that obesity is controllable and risk aversion have direct positive/negative influence on obesity. Socioeconomic variables such as age, gender, income and marital status also had direct causal links with obesity. Weight perception influences individuals body image dissatisfaction. Similarly, belief that obesity is controllable has effect of weight stigma. We also show that risk aversion is influenced by loss aversion and socioeconomic variables such as income, gender and age. From these relationships, 21 hypothesized relationships among the drivers of obesity would be tested.

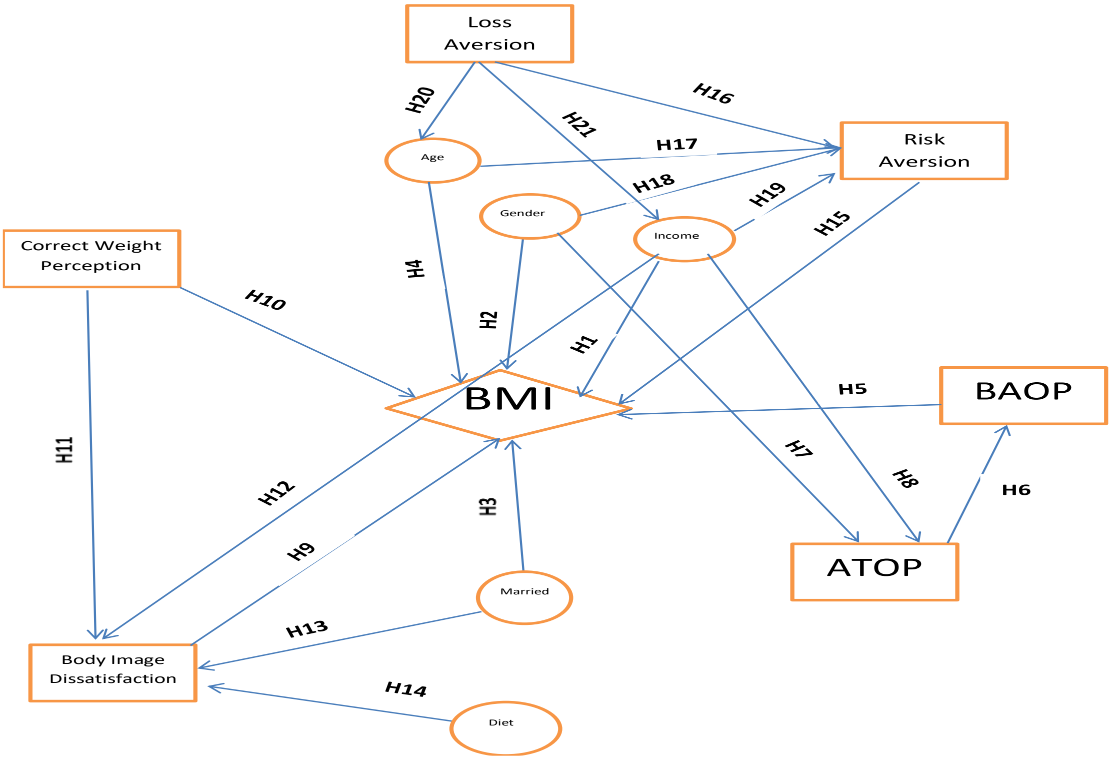


Figure 5-1 Postulated relationships between BMI, behavioural, psychological and socioeconomic factors

5.3 Research Methodology

Sample

The study is based on household and experimental survey carried out in the four provinces of Catalonia. A total of over 180 individuals were surveyed. However, 7 surveys were discarded due to incomplete answers. The distribution of the respondents was based on the 2012 distribution of persons by BMI from the National Health Survey. Survey participants signed a letter of confidentiality before the start of the experiment and were paid 30 euros for completing the survey. Each participant completed the entire questionnaire on an average of 60-75 minutes. The survey questionnaire comprised of questions eliciting risk attitudes of subjects, body image dissatisfaction, weight perceptions, attitudes and beliefs about persons with obesity and body mass index. The experimental procedures are described briefly in the next section.

Measures

Risk attitudes: risk and loss aversion

Respondents elicited their risk and loss aversion coefficients through incentivised lotteries. The goal of using lotteries was to be able to elicit the true behaviour of consumers for monetary gains and losses. The experimental procedure used was based on the seminal work of Tanaka et al. (Tanaka et al., 2010). Individual's utility function indicating their loss and risk aversion were modelled following the Prospect Theory (PT) framework (Kahneman and Tversky, 1979). Mathematically, the utility function following the prospect theory framework can be expressed as follows:

$$PT(x, y; p) = pv(x) + (1 - p)v(y) \qquad (1)$$

where $v(x) = \begin{cases} x^{\sigma} & for\ x \geq 0 \\ -\lambda(-x^{\sigma}) & for\ x < 0 \end{cases}$ (2)

and $w(p) = exp[-(-\ln p)^{\gamma}]$ (3)

PT (*x*, *y*; *p*) is the expected prospect value over binary prospects consisting of the outcome (*x*, *y*) with the corresponding probability (*p*, 1 − *p*). In our experiment, (*x*, *y*; *p*) is specified for plan A and plan B in all scenarios. Note that the value function *v*(*x*) should be estimated with x^{σ} for $x > 0$ or $-\lambda(-x^{\sigma})$ for $x < 0$. The parameter σ represents concavity of the value function (risk aversion) – high values indicate respondents are risk loving, λ represents the degree of loss aversion – high values indicating respondents are more loss averse, and γ is a proxy for the nonlinear probability weighting.

To elicit the three PT parameters (σ, λ, and γ), respondents were given three series of games that contained 35 pair-wise choices. Appendix 5A shows the 3 series of games consisting of plan A and plan B. Series 1 consists of 14 pairwise games. Series 2 consists of 14 pairwise games, and Series 3 consists of 7 pairwise games. Each respondent had three options: a) choose Plan A throughout all games; b) choose Plan B throughout all games; and c) choosing Plan A for a certain number of games and then switch to Plan B for the rest. Individuals who are more averse to loss would choose Plan A a greater number of times over Plan B in both series 1 and 2.

Table 5-1 Switching point (question) in Series 1 and 2, and approximations of σ (parameter for the curvature of power value function/risk parameter)

σ	**Switching point for series 1**														
Series 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Never
1	1.50	1.40	1.35	1.25	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.65	0.55	0.50
2	1.40	1.30	1.25	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.60	0.55	0.50
3	1.30	1.20	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45
4	1.20	1.15	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45	0.40
5	1.15	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45	0.40	0.35
6	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35
7	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30
8	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25
9	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20
10	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.20
11	0.80	0.70	0.65	0.60	0.65	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.15
12	0.75	0.65	0.60	0.55	0.50	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.20	0.15	0.10
13	0.65	0.60	0.55	0.50	0.45	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.15	0.10	0.10
14	0.60	0.55	0.50	0.45	0.40	0.35	0.35	0.30	0.25	0.20	0.15	0.10	0.10	0.10	0.05
Never	0.50	0.45	0.40	0.40	0.35	0.30	0.30	0.25	0.20	0.15	0.10	0.10	0.05	0.05	0.05

The switching points in series 1 and series 2 were used to calculate the average risk aversion and probability weighting parameter (Tanaka et al., 2010). Derived risk aversion estimates[34] are shown in Table 5-1. Based on the risk aversion estimates individuals can be categorize as being risk averse (if σ<1), risk neutral (if σ=1) and risk loving (if σ>1). The loss aversion parameter was calculated by formulating inequalities involving the switching points in Series 3 (see Tanaka et al., 2010). Similarly, for the loss aversion estimates, individuals were either loss averse ($\boldsymbol{\lambda}$>1) or not ($\boldsymbol{\lambda}$<1).

Body Image Satisfaction and Weight Perception

To determine individuals body image satisfaction, the Stunkard scale (Stunkard et al., 1983) was used after a thorough review. The reliability of the Stunkard scale has been confirm in social science research (Cheung et al., 2011; Thompson and Altabe, 1991). The Stunkard scale in **Figure 5-2** presents visual figures that represents nine gender-specific body-shape silhouettes ranging from very thin (assigned a value of 1) to very big (assigned a value of 9).

Respondents were asked to choose from the nine body shapes which silhouette best represented their "current shape" and then their "preferred shape". We classified the Stunkard figure rating scale (SFRS) figures as underweight (Figures 1 and 2), normal weight (Figures 3 and 4), overweight (Figures 5 to 7), and obese (Figures 8 and 9). The difference between perceived current body shape and preferred body shape was used to determine the degree of body image dissatisfaction. Values approaching zero reflect less discrepancy (i.e. the respondent chose the same figure to represent their current size and their ideal size). Based on the results from **Figure 5-2**, participants can be classified into three groups: (1) satisfied with current body shape (current = preferred), (2) desired to be thinner (current > preferred), and (3) desired to be heavier (current < preferred). We also considered, weight misperception among our respondents based on the variation between subject's choice of "current weight" and their measured weight status. If the individual's current weight from the Stunkard scale is equal to the measured BMI, then the individual has the correct perception about their weight. However, if the measured BMI is higher (or lower) than the figure chosen on the Stunkard scale as the current image then the individual has a wrong perception about their weight. Thus, negative and positive scores indicated that the

[34] A full description of the experiment and derivation of the parameter estimates has been provided in an online supplementary file.

individuals perceive themselves as thinner or weightier than the ideal, respectively, whereas a zero score indicated correct weight perception.

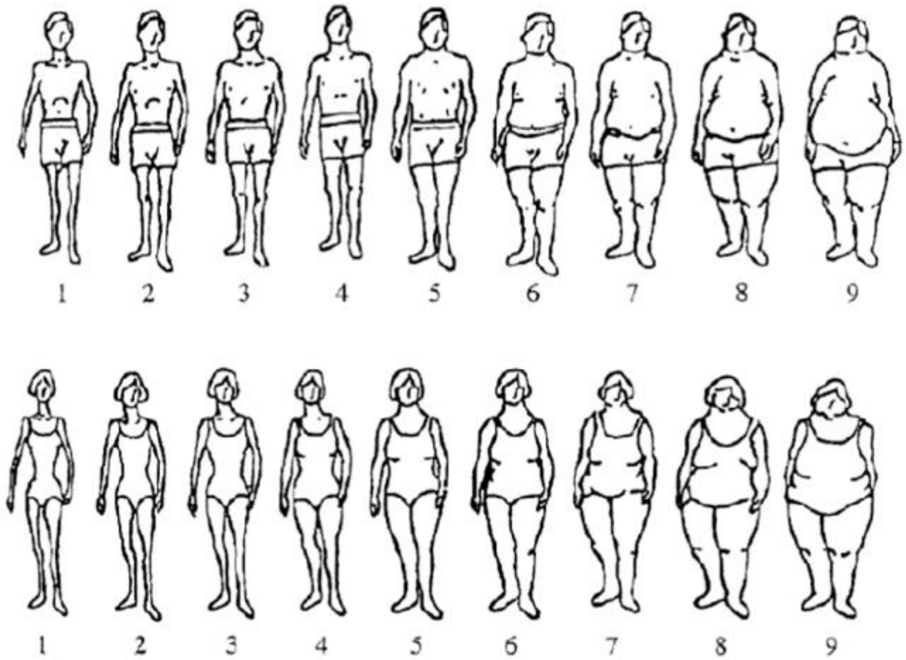


Figure 5-2 Stunkard Scale

Attitudes and Beliefs About Persons With Obesity

Attitudes towards people with obesity (ATOP) and beliefs about people with obesity (BAOP) scales were developed in 1991 (Allison et al., 1991). The estimates of ATOP and BAOP shows extent of individuals' attitudes (positive or negative) and perception (positive or negative) about obesity. ATOP scores range from 0-120 across 20 items; where low (high) scores represent negative (positive) attitudes towards people with obesity (see Appendix 5B). Similarly, BAOP scores also ranged from 0-48 across 8 items as shown on Appendix 5C, where low (high) scores represent a stronger (lesser) belief that obesity is controllable. Standardized values of ATOP and BAOP estimates[35] were used in our analysis for comparison purposes.

Weight status outcomes

Body weight and standing height were directly measured by providing respondents with weighing scale and stadiometer to measure their weights and heights after the interview. Body Mass Index

[35] See supplementary file for derivation

(BMI=weight/height^2, kg/m^2) were calculated for each subject. Individuals were categorized into four different weight groups: as underweight (BMI<18.5 kg/m^2), normal weight (BMI between 18.5–24.9 kg/m^2), overweight (BMI between 25–29.9 kg/m^2), and obesity (BMI ≥30 kg/m^2) (Organization and others, 2014). For the purpose of our analysis, standardized BMI's were used for the analysis.

Analytical Procedure: Structural Equation Modelling

Path model analysis was used to estimate the strength and direction of correlation among the covariates that were considered in our data. SEM provides the option to test the overall goodness of fit of the model and the significance of the path coefficients (Steinberg, 2004). In path model analysis, there are two types of variables linked by arrows. The direction of the arrows gives indication about the hypothesized paths and the direction of influences (Keith, 1988). Variables with arrows emanating from them are exogenous variables. This does not override the fact that, endogenous variables can be both dependent and independent variables (Klem, 1995). On the other hand, endogenous variable has several arrows coming toward it and its value is explained by one or more of the other variables (Lomax and Schumacker, 2004).

The magnitude and sign of the path estimates indicate the degree and direction of effects that is postulated to exist among a set of variables (Lomax and Schumacker, 2004). The effects of the path coefficients can be decomposed into direct, indirect, and total effects. A direct effect indicates the relationship between two variables with no mediating (intervening) variables (Steinberg, 2004). Indirect effect indicates the effect of an independent variable on a dependent variable when one or more mediating variables intervenes (Foster et al., 2006). Total effect is simply the summation of the direct and indirect effects.

5.4 Results

Descriptive Statistics

Variables that were used in the path analysis model are shown in **Table 5-2**. In general, individuals are risk averse and more averse towards losses. Only 24% of the respondents followed a strict diet. About 70% and 69% of the respondents were female and married, respectively. Those with only basic education were in the minority, representing 8% of the total sample.

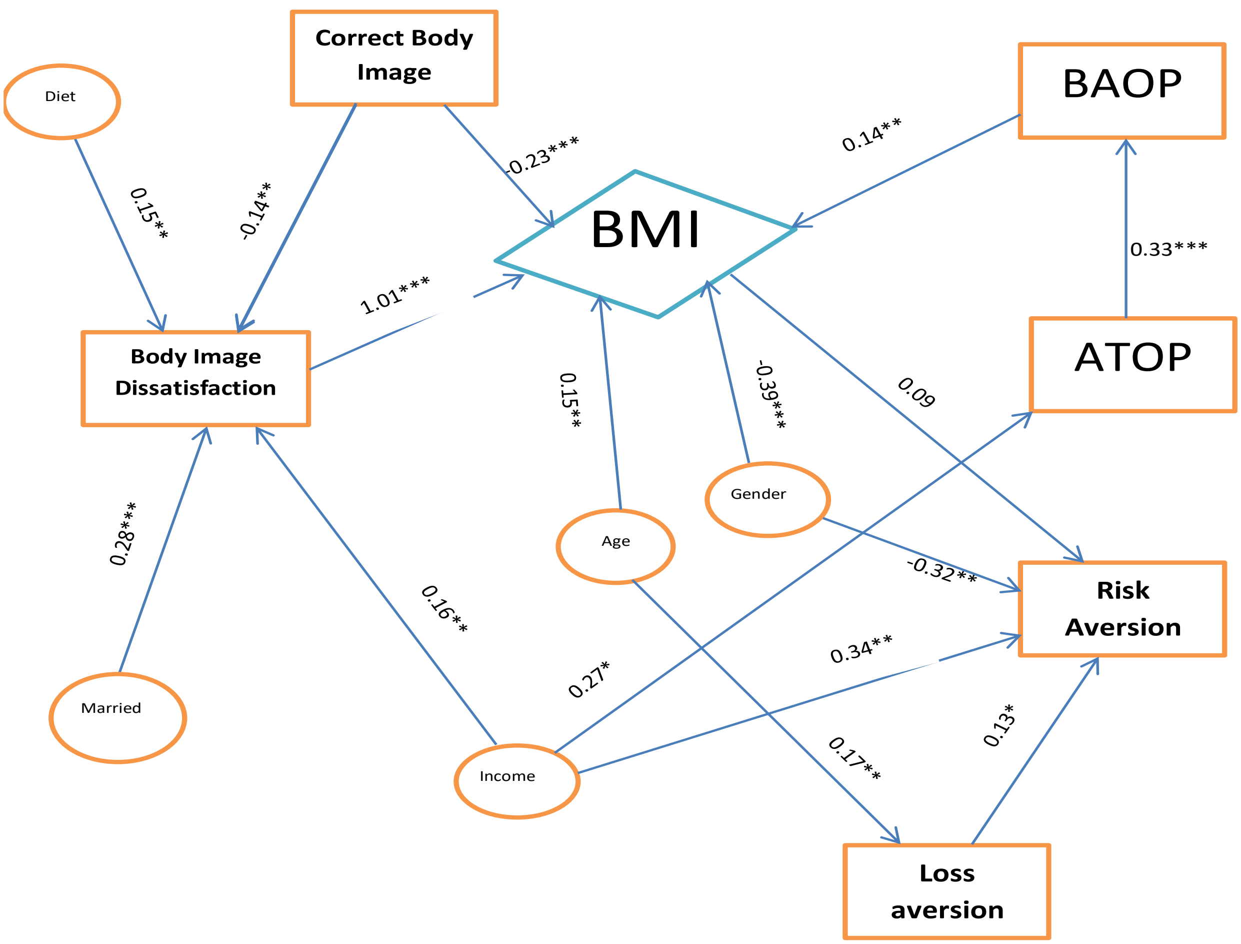
Individuals who earned the average income represented 32% of the total sample, indicating that majority of the respondents earn more than the average salary. Our data shows that the average individual in our sample is within the middle age category, with an average age of 46 years. Even though, the average BMI was about 25.17, about 73% of the respondents were dissatisfied with their body image while individuals with correct body weight perception were about 63% of the total sample.

Table 5-2 Sociodemographic Description of The Sample

Sociodemographic characteristics	Mean	Stand Error
Belief about people with obesity	21.65	0.33
Attitudes towards people with obesity	65.33	1.14
Risk aversion coefficient	0.58	0.03
Loss aversion coefficient	3.67	0.30
Individuals on diet	0.24	0.04
Gender	0.70	0.04
Married	0.69	0.04
Age	46.38	1.11
Basic Education	0.08	0.02
Income < 1000 EUR	0.32	0.04
Body image dissatisfaction	0.73	0.03
Body mass index	25.17	0.32
Correct body image perception	0.63	0.04

Structural Model

The results of the path model are presented in Figure 5-3. This model had a goodness fit with a chi-square = 20.31 (df = 28, P = 0.85), RMSEA< 0.00 and SRMR<0.05. Based on the p-value of the chi-square estimate we do not reject the null hypothesis of perfect fit of the model. Similarly, the RMSEA and SRMR both have a p-value < 0.05 indicating that our conceptual model is well fitted. Figure 5-3 shows the estimated conceptual framework composing of psychological factors, risk attitudes, BAOP, and some sociodemographic. The conceptual model does not support the assumption of direct relationship between body mass index and risk aversion and belief about obese persons.



Model Fit: RMSEA - 0.00; SRMR - 0.03; Chi-square Test Statistic - 20.31; Degrees of freedom - 28.00; P-value (Chi-square) - 0.85

Figure 5-3 Estimated Structural Model

Body Mass Index

Summary of the hypotheses are displayed on

. Hypothesis 1 and hypothesis 3 are not supported in our model. These suggest socioeconomic status and marital status do not influence the development of BMI. Hypothesis 2 is supported by

Hypothesis	Description	Decision
H1	Income is positively related to BMI	Not Supported
H2	Women are associated with higher BMI values	Supported
H3	Married persons are associated with higher BMI values	Not Supported
H4	Age is positively correlated with BMI	Supported
H5	Positive attitudes towards obese people is positively associated with the belief that obesity is uncontrollable	Supported
H6	Persons who belief obesity is controllable have a higher body mass index	Supported
H7	Women will tend to exhibit more negative attitudes towards obese people	Not Supported
H8	Persons with higher socioeconomic status (measured by income) exhibit weight stigma	Supported
H9	Persons with a higher BMI also exhibit a higher dissatisfaction with their bodies	Supported
H10	Persons with correct weight perception have a lower body mass index	Supported
H11	Persons with correct weight perception are also more satisfied with their body	Supported
H12	Body image dissatisfaction is positively associated to socioeconomic status	Supported
H13	Body image dissatisfaction is positively associated with marriage	Supported
H14	Persons who are on diet are more dissatisfied with their bodies	Supported
H15	Risk aversion is negatively associated with body mass index	Not Supported
H16	Risk aversion is negatively associated with loss aversion	Supported
H17	Risk aversion increases with individual's age	Not Supported
H18	Females are more risk averse than males	Supported
H19	Risk aversion increases with socioeconomic status	Supported
H20.	Loss aversion increases with age	Supported
H21.	Loss aversion increases with socioeconomic status or income	Not Supported

our model with a path coefficient significant at 1 percent level. Hypothesis 4 is also supported in our model at 5% significant level. Hypotheses 2 and 4 suggest that women and older people have the tendency to develop higher body mass index.

Table 5-3 Description of hypotheses relating drivers of body mass index

Hypothesis	Description	Decision
H1	Income is positively related to BMI	Not Supported
H2	Women are associated with higher BMI values	Supported
H3	Married persons are associated with higher BMI values	Not Supported
H4	Age is positively correlated with BMI	Supported
H5	Positive attitudes towards obese people is positively associated with the belief that obesity is uncontrollable	Supported
H6	Persons who belief obesity is controllable have a higher body mass index	Supported
H7	Women will tend to exhibit more negative attitudes towards obese people	Not Supported
H8	Persons with higher socioeconomic status (measured by income) exhibit weight stigma	Supported
H9	Persons with a higher BMI also exhibit a higher dissatisfaction with their bodies	Supported
H10	Persons with correct weight perception have a lower body mass index	Supported
H11	Persons with correct weight perception are also more satisfied with their body	Supported
H12	Body image dissatisfaction is positively associated to socioeconomic status	Supported
H13	Body image dissatisfaction is positively associated with marriage	Supported
H14	Persons who are on diet are more dissatisfied with their bodies	Supported
H15	Risk aversion is negatively associated with body mass index	Not Supported
H16	Risk aversion is negatively associated with loss aversion	Supported
H17	Risk aversion increases with individual's age	Not Supported
H18	Females are more risk averse than males	Supported
H19	Risk aversion increases with socioeconomic status	Supported
H20.	Loss aversion increases with age	Supported
H21.	Loss aversion increases with socioeconomic status or income	Not Supported

Beliefs and Attitudes
Hypothesis 5 is supported by our model at 5 percent significant level indicating a positive association between belief that obesity is controllable and body mass index. Hypotheses 6 is significant and suggest a strong relationship between positive attitudes and belief that obesity is controllable. Hypothesis 7 was not supported by our model, however, hypothesis 8 suggest negative effect of socioeconomic status or income on attitudes towards persons with obesity.

Body Image Dissatisfaction and Weight Perception
Persons who are dissatisfied with their bodies have higher body mass index (supported by Hypothesis 9). Hypothesis 10 is supported and indicate that individuals who have lower body mass index had perceived their weight accurately. Hypothesis 11 also suggest that those who had the right weight perception were not dissatisfied with their body image. Hypothesis 13 and hypothesis 14 suggest that only two sociodemographic characteristics: marital status and dieting has influence on body image dissatisfaction.

Risk Attitudes: Risk and Loss Aversion
Impact of risk attitudes on body mass index and other constructs were measured by hypotheses 15 – 19. Hypotheses 15 and 17 are not supported by our conceptual model. Hypothesis 16 is supported and suggests that risk lovers are usually loss averse. Hypotheses 18 and 19 are supported by our model at 5% significant level. They tend to suggest older and female subjects are more averse to risk. Hypotheses 20 and 21 relate loss aversion with two socioeconomic constructs: age and income. Income did not have any significant influence on loss aversion, however, loss aversion tends to increase with age.

5.5 Discussions
This study aimed at identifying paths through which different variables affect body mass index. On the basis of our estimated conceptual framework, we have categorised our variables into: body mass index, BAOP, ATOP, risk attitudes, and weight perception/body image dissatisfaction.

First, Figure 5-3 shows that some variables directly influence body mass index whiles others tend to have indirect effect on body mass index. Correct weight perception not only affect body mass index directly but also indirectly through body image dissatisfaction. This result directly support previous findings that reported that people with obesity are dissatisfied with their body image than normal weight persons (Ålgars et al., 2009; Weinberger et al., 2016). Gender and age are the two demographic characteristics that significantly affect body mass index. Females tend to have higher body mass index than their male counterparts. Similarly, older people exhibit higher body image than younger people. These results confirm findings in Spain that showed that socioeconomic status plays a major role in the high prevalence of obesity (Costa-Font and Gil, 2006). For instance, the prevalence of obesity has been found to be higher in females than males and tend to rise with age (Aranceta-Bartrina et al., 2016).

Second, body image dissatisfaction was found to be directly related to marital status, diet and income levels. Contrary to past studies, we found no direct link between body image dissatisfaction and education, however, as lower income people tend to be more dissatisfied with their body image probably due to the high cost of maintaining normal body weights(Luo et al., 2005). Moreover, we confirm that individuals who are married tend to be dissatisfied with their body image (Friedman et al., 1998). Finally, this study confirms that individuals who are dissatisfied with their body image follow restrictive dietary pattern (de Cássia Ribeiro-Silva et al., 2018).

Third, we did not find any direct relationship between ATOP (weight stigma) and body mass index, however, there was an indirect relationship through BAOP with obesity, indicating a direct relationship between BAOP and body mass index. The BAOP estimate suggests that people with higher body mass index belief that obesity is not under the control of people with obesity. Also, the positive relationship between ATOP and BAOP scores confirms that individuals who belief that obesity is not under the control of people with obesity exhibit a more positive attitude. A similar results was found among psychology students in Mexico (Soto et al., 2014).

Finally, our findings did not support previous findings that found that obese and overweight persons are less risk averse (or more loss averse) (Davis et al., 2010). However, there was direct relationship between risk aversion and loss aversion, gender and income. Females were found to be more loss averse than males (Rosen et al., 2003). Contrary to past literature, individuals who are in the lower income strata were less averse towards risk (Dohmen et al., 2011).

5.6 Conclusions

The primary purpose of this study was to examine inter-relations between psychological attitudes, believes and attitudes towards obesity, body perception and dissatisfaction and obesity among adult population in Catalonia by using a path modelling approach. We began with a conceptual framework relating all the factors that literature suggests to influence the development of obesity.

Such an analysis is necessary due to the incomplete nature of empirical studies linking obesity to these factors.

We used the path modelling approach of structural equation to estimate a multilevel regression model. Our results suggest significant direct and indirect relationships between obesity and the factors considered. In addition, significant relationships were found among some factors. First, persons who believe that obesity is under the control of persons with obesity tend to have higher body mass index; persons who have lower body mass index perceived their weight correctly and vice versa; and persons with body image dissatisfaction tend have higher body mass index. Second, persons who believe that obesity is under the control of persons with obesity show positive attitudes towards persons with obesity. While males tend to have lower body mass index, older persons tend to have higher body mass index compared to younger ones.

Several notable strengths to this study include the consideration of experimental data, the use of a structural equation analysis, and pathways that link psychological factors, socioeconomic characteristics, attitudes and perceptions about obesity, body image problems and obesity. However, our results should be interpreted with caution due to some limitations. First, because the data is few, generalization of the results must be done with caution as this is not a representative of the whole Catalan population. Second, factors such as genetic factors were not included due to cost of obtaining such information. Only adult population were considered in our analysis, indicating that result cannot be generalized to include children and adolescents.

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CHAPTER 6

CONCLUDING REMARKS, LIMITATIONS AND FURTHER RESEARCH

6.1 Summary

Current food consumption patterns in industrialized countries are having a detrimental impact on both human health (obesity and health cost) and the environment (CO_2-eq emission). In this context, it is essential to raise public awareness concerning the negative environmental and nutritional impacts of our food choices. The Double Pyramid Model based on the Mediterranean dietary requirement establishes a strong correlation between the environmental impact of food and their nutritional characteristics. This suggests that nutritional and environmental goals can simultaneously be achieved from either the environmental or health context in Spain. However, policies that simultaneously incorporate both goals are usually lacking and/or do not achieve the desired results.

To address the scope limitations and the inability of fiscal policies to achieve anticipated goals this thesis was set out to answer two research questions: 1) Can an environmental and/or health tax change consumer behaviour towards sustainable environmental and health goals without compromising on consumer welfare? and 2) To what extent do behavioural factors predispose consumers to diet related diseases - obesity (low consumer response to existing policies).

In answering the aforementioned research questions, two main goals were defined for the thesis. The first goal was to examine the effectiveness of fiscal policies such as nutrient and environmental taxes on emission reduction, diet quality and consumer welfare under the assumption of rational and well informed consumers. To achieve this goal, two objectives were defined which divided into two chapters. The first chapter simultaneously addresses both environmental and health goals while the second focused primarily on health goals.

The first Chapter evaluated the effectiveness of a Pigovian tax based on social cost of emission on food demand, dietary composition, emission reduction and consumer welfare in Catalonia (Northeast Spain). Alternative tax policy scenarios have been considered, which, in essence, reflect the alternative social cost of emissions or alternative tax magnitudes. The methodological framework has been based on food-at-home expenditure as well as on own- and cross-price elasticities calculated from estimating an EASI food demand system. Taxes based on the EU environmental policy goals generate significant price changes far from their natural variation.

However, simultaneous environmental and diet quality goals can be achieved using moderate environmental taxes. However, the findings confirm that environmental taxes are more regressive on low income households as they tend to spend more on high carbon footprint foods which are cheaper.

The second chapter, specifically addressed the effectiveness of a health (fat) tax on diet quality and consumer welfare. A revenue-neutral tax policy that internalizes the social cost of obesity via a VAT reform (fat tax scheme) was implemented using home scan data from Catalonia was used. Nutrient price and expenditure elasticities were derived from an EASI demand model for the tax simulations. Lipids, saturated fatty acid, sodium, and cholesterol are very responsive to fat taxes. In addition, fat taxes are more effective on obese and overweight persons who usually consume low nutrient foods. The fat tax is a better alternative for government to simultaneously improve the quality of diet and reduce public health expenditure. Welfare-wise, revenue fat taxes could result in expenditure savings for all household segments if efficiently applied.

The second goal was to analyse consumer behaviour from the context of rational addiction drawing from the body of literature in behavioural economics that suggests that consumers are influenced by bounded rationality, social norms, time inconsistency, uncertain outcomes – prospect theory. Also, to achieve this goal, two objectives were defined which were divided into two chapters. The first chapter analysed weight development from the context of aversion towards risk, losses and time inconsistencies. The second chapter developed a framework that brought together all the factors that predispose consumers to obesity.

Chapter 4 estimated and evaluated how risk and time inconsistencies of consumers' influence weight development, a consequence of poor food choices. Prospect theory parameters: risk aversion, loss aversion and probability weighting parameter as well as time preference models :exponential, hyperbolic, quasi-hyperbolic and the general model were estimated. The average consumer was found to be risk averse, loss averse and exhibit time inconsistency decisions. The studied confirmed that risk aversed persons have lower BMI. In addition, impatient persons tend to exhibit higher BMI. Probability weighting, loss aversion, and present bias were not significant predictors of BMI.

Chapter 5 developed a conceptual framework using path analysis to explain how individual bio-psycho-eco-social factors interact to affect the development of obesity in Catalonia. Experimental data on psychological attitudes, believes and attitudes towards obesity, body image perception, body dissatisfaction and body mass index were used. Results confirm the assertion that persons who believe that obesity is not under the control of obese persons have weight problems. In addition, persons with body image dissatisfaction tend have higher body mass index. Persons who have lower body mass index perceived their weight correctly and vice versa. Second, pro-weight attitudes are exhibited by people who believe that obesity is controllable. From the gender context, males tend to take care of their weight than females; age-wise, people tend to take less care of their weights as they grow older.

6.2 Policy Implications

This section presents the implications of the results derived from the four objectives proposed in the introduction. First, environmental taxes have implication for the environment, health and diet. In fact, this confirms the importance of the double food pyramid for both health and environmental policies. In addition, environmental taxes must be significantly high to achieve the most effective impact on health and environment due to the inelastic nature of products with high carbon footprint. However, precautions should be taken as environmental taxes heterogeneously reduces the real income of different segments of consumers. Government must therefore decide on the level of trade-off between environmental, health and economic goals of consumers.

Similarly, health taxes have implications for the consumer diet, welfare and the health sector of the state. Unlike environmental taxes, health taxes have positive impact on consumer welfare i.e. result in expenditure savings across all consumer segments. Fat taxes provide effective and efficient way to internalise the social cost of obesity. Taxes based on nutrient elasticities rather product demand elasticities have better impact on diet quality.

Individual behaviours are deeply influenced by factors that are not accounted for in economic policies targeted at non-communicable diseases - obesity. Integrating consumer behaviours into economic policy modelling could provide an opportunity to improve policy impacts. In addition, targeted policies are required instead of a single policy targeted at heterogeneous consumers. Finally, since consumers can not usually follow through on best food choices or plans (time inconsistent) to reduce consumption of such sin goods, taxation acts as a commitment device.

Furthermore, policies directed towards weight loss should be gender-tailored, especially among individuals with body image dissatisfaction. Similarly, there is the need for anti-weight bias attitude interventions in the Catalonia. For instance, education programs stressing the uncontrollability of obesity is important among Catalan adults. In addition, educational programs should be targeted at stressing the importance of emotional qualities, character and individuality as key components of beauty should be implemented.

6.3 Limitations and Future research

First, a policy setback from this study (Chapter one and Chapter two) could be border trade problems. The significant differential between the prices of products sold in Catalonia, after the carbon/fat tax imposition, and the same products sold in neighbouring regions or countries could trigger a similar effect like the Danish fat tax. Future research should integrate spill over effects of taxes into economic modelling as this have the potential to reduce the impact of the tax. Comparison of the elasticity estimates for subjects along the border and those off-border could be interesting.

Second, in the demand estimations, the study assumed that the food supply function is perfectly elastic ignoring the potential strategic decisions of firms. Further research could be focused on relaxing this assumption by taking into account the interaction between demand and supply in determining the post-tax price.

In addition, a strong separability between food-at-home and food-away-from-home, other durable and non-durable goods was assumed due to data unavailability. On the other hand, this limitation is difficult to overcome as we would need, at least, a composite indicator of GHG emissions of other durable and non-durable goods.

Policies based on our welfare estimates should be interpreted with caution as elasticities used were derived from incomplete food-at-home demand elasticities which have the potential to bias our conclusions. Future research could estimate complete food demand elasticities and compare the welfare estimates with our results.

Results from the behavioral modelling should be interpreted taking into account the following limitations. First, since the data is few, generalization of the results must be done with caution as this is not a representative of the whole Catalan population. Future research could replicate the study in other parts of Spain or increase the sample size to represent the population of study.

Second, the estimation of the path modelling did not take into account genetic factors as such future research could incorporate genetic factors in the structural equation modelling to have a holistic view of the determinants of body mass index.

In addition, our sampling population are adult indicating that result cannot be generalized to include children and adolescents. As such future research can be based on these age groups and compare with our results.

Future research could examine the efficacy of interventions to modify both implicit and explicit anti-fat attitudes and identify explanations for differences in obesity perceptions in subgroups of the population.

Future research could start the analysis from the behavioural level to understand factors that influence consumers reaction to taxes and subsidies. Understanding the factors that influence how consumers react to tax is very important for the tax policy development and implementation. From the behavioural level, consumers tend to react to taxes more than subsidy. Furthermore, consumers react more when the taxes are increased gradually than when the tax is imposed at once. This suggest that a dynamic demand model would be the best approach to modelling the tax policies.

Second, there is the need for future research to incorporate behavioural attitudes into the EASI demand modelling. For instance, the elasticities of the risk preferences parameters could be estimated to understand how risk averse or loss averse individuals respond to fiscal policies. In the same way the welfare impact of the tax policies could be analysed for different individuals depending on their risk, loss and time inconsistency elasticities.

Understanding how weight stigmatisation influence the extent to which overweight and obese people react to taxes has not yet been studied. Future research could toe this line to explain how such behaviours increase/decrease the propensity to be overweight or obese.

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Appendix 2A

Estimating of the Fisher price indices

To illustrate the procedure, let us consider the fish and sea food category.

1) In the first stage, since each product is uniquely identified by a particular barcode, we calculated the unit value U_{gji} for all food items with the same barcode under each sub-category *g* within aggregate food group *j* for household *i* using:

$$\boldsymbol{U_{gji}} = \frac{\sum_{v=1}^{V} p_{mgj}^{i} * q_{mgj}^{i}}{\sum_{v=1}^{V} q_{mgj}^{i}} \tag{A.1}$$

where p_{mgj}^{i} represents the price of food with barcode *m* paid for by individual *i* for sub-category product *g* within the food group *j* and $q_{mgj}^{i}$is the quantity of product with barcode *m* paid for by individual *i* for sub-category product *g* within aggregate food group *j*.

2) In the second stage, unit values obtained from (A.1) (U_{gji}) were used to calculate the Laspeyeres and Paache price indices for each food group *j* using the following expressions:

$$\boldsymbol{P_j^i} = \frac{\sum U_{gj}^{i} * q_{gj}^{i}}{\sum U_{gj} * q_{gj}^{i}} \tag{A.2}$$

and

$$\boldsymbol{L_j^i} = \frac{\sum U_{gj}^{i} * q_{gj}}{\sum U_{gj} * q_{gj}} \tag{A.3}$$

where U_{gj}^{i} is the unit value for the aggregate product *g* within food category *j* for household *i* as defined in (A.1), U_{gj} is the unit value for the aggregate product *g* within food category *j* for the average household, and q_{gj} is the average quantity purchased for aggregate product *g* within food category *j* for the average household; P_j^i and L_j^i represent the Laspeyres and Paasche price indices for individual *i*'s food group *j*, respectively.

3) In the final stage, we estimated the Fisher price indices (the geometric mean of the Laspeyeres and Paache indices) for each food group *j* and household *i* using:

$$\boldsymbol{F_j^i} = \sqrt{\boldsymbol{P_j^i} * \boldsymbol{L_j^i}}$$

Appendix 2B

Food demand and nutrient elasticities

- Hicksian elasticity, $\boldsymbol{\epsilon_{kj}}$ of demand for good *k* with respect to the price of the good *j* was derived as:

$$\boldsymbol{\epsilon_{kj}} = \frac{(\boldsymbol{A_{kj}} + \boldsymbol{B_{kj}}\tilde{\boldsymbol{y}})}{\boldsymbol{w_k}} + \boldsymbol{w_j} - \boldsymbol{\delta_{kj}} \quad \text{(B.1)}$$

where δ_{kj} =1 if *k* =j, and 0 otherwise.

- The vector of 16 food expenditure elasticities $\boldsymbol{\vartheta}$ were subsequently derived as:

$$\boldsymbol{\vartheta} = (\boldsymbol{diag}(\boldsymbol{\gamma}))^{-1}[(\boldsymbol{I_j} + \boldsymbol{\sigma\omega'})^{-1}\boldsymbol{\sigma}] + \boldsymbol{1_j} \quad \text{(B.2)}$$

where $\boldsymbol{\gamma}$ is the $J \times 1$ vector of observed budget shares, $\boldsymbol{\sigma}$ is a $J \times 1$ vector whose *n*-th element equals $\sum_{r=0}^{5} rE_{rj}\tilde{y}^{r-1} + \sum_{l=0}^{L} D_{lj}z_l + \sum_{k=1}^{J} B_{kj}P_k$, $\boldsymbol{\omega}$ is the $J \times 1$ vector of log prices, and 1_j is a $J \times 1$ vector of ones.

- The Marshallian elasticity of demand, $\boldsymbol{\varepsilon_{kj}}$, was derived from the Slutsky equation using:

$$\boldsymbol{\varepsilon_{kj}} = \boldsymbol{\epsilon_{kj}} - \boldsymbol{w_j} * \boldsymbol{\vartheta_n} \quad \text{(B.3)}$$

where $\boldsymbol{\vartheta_n}$ is the *n*-th element of $\boldsymbol{\vartheta}$

After computing the matrix of price and expenditure elasticities in (B1–B3), the next step is to calculate the matrix of nutrient elasticities (see Huang, 1996). The matrix of nutrient elasticities Ψ can then be obtained by pre-multiplying the matrix of food aggregate nutrient shares ζ and the matrix of own and cross-price demand elasticities Θ.

$$\boldsymbol{\Psi} = \boldsymbol{\zeta} * \boldsymbol{\Theta} \quad \text{(B.4)}$$

where $\boldsymbol{\Psi}$ is the *n x (j+1)* matrix of nutrient elasticities in response to changes in food prices and expenditure (*n* indicates the number of nutrients and *j* the number food products), $\boldsymbol{\zeta}$ is the *n x j* matrix with entries in each row indicating the food commodity's share of a particular nutrient, and $\boldsymbol{\Theta}$ is the *(j x j+1)* matrix of demand elasticities

Appendix 3C

Mean nutrient elasticities

	Grains	Vegetables	Starchy roots	Fruit, veg juices	Beef, veal and lamb	Pork	Poultry	Processed meats	Fish	Milk and deriv.	Cheese	Sugar & desert	Plant-based fats	Composite dishes	Snacks and other foods	Expenditure
Total Energy (kJ)	-0.10	-0.14	-0.01	-0.23	-0.01	0.00	-0.10	-0.03	-0.03	-0.23	0.00	-0.05	-0.09	-0.01	0.09	0.86
Total Energy (kcal)	-0.09	-0.14	-0.01	-0.23	-0.01	0.00	-0.10	-0.03	-0.03	-0.23	0.00	-0.05	-0.09	-0.01	0.10	0.86
Total Lipid	-0.07	-0.14	-0.03	-0.22	0.02	-0.03	-0.11	-0.08	-0.04	-0.22	-0.04	-0.07	-0.11	-0.03	0.09	0.84
Total Protein	-0.05	-0.15	0.04	-0.22	-0.02	-0.08	-0.14	-0.06	-0.07	-0.23	-0.03	-0.01	-0.01	-0.01	0.11	0.98
Water	-0.07	-0.15	0.07	-0.37	-0.07	0.01	-0.05	0.04	-0.06	-0.17	0.05	0.07	0.05	0.04	0.08	1.09
Total Dietary Fibre	-0.15	-0.18	-0.01	-0.36	-0.02	0.05	-0.02	0.06	-0.01	-0.13	0.03	0.04	-0.02	0.01	-0.06	0.90
Carbohydrate	-0.16	-0.14	-0.01	-0.26	-0.03	0.08	-0.06	0.04	0.00	-0.24	0.06	-0.04	-0.11	0.03	0.09	0.81
Fatty Acid 22:6 n03	0.04	-0.16	0.11	-0.25	-0.02	-0.39	-0.10	-0.07	-0.20	-0.17	0.05	0.05	-0.01	-0.14	0.14	1.01
Mono-unsaturated Fatty Acid (g)	-0.07	-0.14	-0.04	-0.22	0.02	-0.05	-0.11	-0.09	-0.05	-0.21	-0.03	-0.06	-0.12	-0.03	0.07	0.84
Poly-unsaturated Fatty Acid (g)	-0.11	-0.12	-0.06	-0.24	-0.01	-0.01	-0.09	-0.02	-0.05	-0.20	0.06	-0.05	-0.21	-0.05	0.10	0.85
Saturated Fatty Acids	-0.05	-0.15	0.00	-0.19	0.04	-0.02	-0.12	-0.11	-0.04	-0.24	-0.12	-0.09	-0.05	-0.01	0.09	0.82
Fatty Acid 12:0 (lauric)	0.05	-0.20	-0.03	-0.17	0.02	0.22	-0.10	-0.08	0.01	-0.19	0.07	-0.62	0.00	0.03	0.36	0.52
Fatty Acid 14:0 (myristic acid)	-0.01	-0.17	0.02	-0.16	-0.07	0.05	-0.09	-0.10	-0.02	-0.27	-0.02	-0.23	-0.02	0.00	0.19	0.74
Fatty Acid 16:0 (palmitic acid)	-0.05	-0.15	-0.05	-0.21	0.01	-0.05	-0.10	-0.11	-0.04	-0.21	0.00	-0.12	-0.12	-0.05	0.09	0.76
Fatty Acid 18:0 (stearic acid)	-0.03	-0.16	-0.05	-0.20	0.01	-0.06	-0.09	-0.12	-0.04	-0.21	0.01	-0.17	-0.09	-0.04	0.11	0.74
Fatty Acid 18:1 n09 cis (oleic acid)	-0.10	-0.12	-0.08	-0.24	0.00	-0.05	-0.08	-0.06	-0.05	-0.19	0.05	-0.07	-0.23	-0.05	0.06	0.80
Cholesterol (mg)	-0.02	-0.14	0.01	-0.21	0.02	0.00	-0.29	-0.05	-0.07	-0.19	-0.09	-0.08	0.04	-0.04	0.19	1.13
Fatty Acid 18:2	-0.12	-0.12	-0.08	-0.24	-0.01	0.02	-0.08	-0.01	-0.04	-0.18	0.09	-0.11	-0.28	-0.07	0.10	0.77
Fatty Acid 18:3	-0.09	-0.12	-0.05	-0.24	-0.12	-0.03	-0.08	-0.05	-0.04	-0.19	0.07	-0.10	-0.20	-0.04	0.11	0.85
Fatty Acid 20:4 n06 (ácido araquidónico)	-0.02	-0.16	0.05	-0.25	-0.32	-0.49	-0.09	-0.12	-0.10	-0.19	0.07	0.04	0.01	-0.02	0.08	1.03
Fatty Acid 20:5	-0.04	-0.12	0.12	-0.30	-0.86	-0.18	-0.05	0.04	-0.04	-0.18	0.20	0.03	-0.03	-0.05	0.16	1.16
Vitamin A	-0.07	-0.20	0.05	-0.30	0.01	0.04	-0.07	0.00	-0.04	-0.16	-0.02	-0.02	0.04	0.00	0.05	1.03
Vitamin D	-0.06	-0.13	0.06	-0.20	0.01	-0.07	-0.15	0.00	-0.11	-0.24	0.03	0.00	-0.09	-0.07	0.17	1.00
Viamin E	-0.13	-0.13	-0.04	-0.30	-0.02	0.02	-0.06	0.03	-0.05	-0.16	0.07	-0.01	-0.18	-0.04	0.06	0.91
Folate	-0.14	-0.17	0.01	-0.37	-0.02	0.05	-0.07	0.06	-0.02	-0.13	0.01	0.05	0.02	0.05	0.02	1.07
Niacina	-0.10	-0.15	0.02	-0.29	-0.05	-0.10	-0.12	-0.01	-0.06	-0.17	-0.01	0.03	-0.04	-0.03	0.07	1.00
Riboflavin	-0.12	-0.13	0.03	-0.24	-0.05	0.00	-0.12	0.01	-0.03	-0.25	0.00	0.03	-0.07	0.03	0.10	1.00
Thiamin	-0.13	-0.14	0.07	-0.16	-0.09	-0.08	-0.06	-0.03	-0.03	-0.37	0.07	0.07	-0.08	0.05	0.09	0.95
Vitamin B12	0.02	-0.16	0.07	-0.22	0.00	-0.14	-0.14	-0.07	-0.13	-0.21	-0.01	0.01	-0.01	-0.13	0.14	0.98
Vitamin B6	-0.14	-0.14	0.02	-0.33	-0.06	-0.04	-0.08	0.04	-0.04	-0.16	0.01	0.06	-0.04	0.03	0.05	1.02
Vitamina C	-0.12	-0.15	0.07	-0.56	-0.11	0.07	0.05	0.13	-0.04	-0.02	0.08	0.13	0.11	0.11	-0.01	1.17
Calcium	-0.09	-0.15	0.09	-0.16	0.01	0.00	-0.08	-0.05	-0.04	-0.35	-0.08	0.04	-0.02	0.05	0.09	0.92
Iron	-0.11	-0.18	0.02	-0.29	-0.01	-0.05	-0.08	0.01	-0.05	-0.16	0.02	0.01	-0.02	-0.01	0.05	0.99
Potassium	-0.08	-0.16	0.04	-0.32	-0.06	-0.02	-0.05	0.01	-0.05	-0.20	0.04	0.05	0.02	0.04	0.07	1.02
Magnessium	-0.12	-0.16	0.02	-0.27	-0.03	-0.01	-0.07	0.01	-0.03	-0.22	0.02	0.02	-0.04	0.02	0.06	0.94
Sodium	-0.04	-0.17	0.01	-0.22	0.02	-0.16	-0.10	-0.10	-0.07	-0.20	-0.06	0.00	-0.03	-0.08	0.04	0.87
Phosphorus	-0.08	-0.15	0.05	-0.21	-0.02	-0.04	-0.11	-0.03	-0.05	-0.27	-0.04	0.03	-0.03	0.00	0.09	0.95
Iodine	-0.05	-0.14	0.09	-0.18	-0.01	-0.05	-0.12	-0.03	-0.08	-0.31	0.03	0.01	-0.03	0.01	0.15	1.02
Selenium	-0.07	-0.14	0.04	-0.27	-0.04	-0.09	-0.14	0.00	-0.09	-0.18	0.00	0.02	-0.05	-0.05	0.12	1.01
Zinc	-0.09	-0.15	0.01	-0.25	-0.03	-0.06	-0.11	-0.04	-0.05	-0.22	-0.04	0.02	-0.02	0.00	0.07	0.96

Appendix 3D

Mean Marshallian food-at-home demand elasticities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1)	-0.54***	-0.10***	-0.10	-0.32***	0.01	0.06	-0.07	0.20***	0.11	-0.19***	-0.05	0.16***	-0.40***	0.13***	-0.14	0.39
(2)	0.06	-0.58***	0.08	-0.10*	0.21	-0.12	0.03	-0.22**	-0.01	-0.14***	0.01	-0.18**	0.42***	-0.15***	-0.19	0.18
(3)	-0.07***	-0.15***	-0.81***	-0.27***	0.06	0.04	-0.10***	-0.07***	0.01	-0.16***	0.05	-0.04*	-0.07***	-0.05***	0.24***	0.13
(4)	-0.20*	0.12	0.10	-0.99***	-0.35**	0.24	0.10	0.40***	-0.08	0.15***	0.13	0.36***	0.00	0.31***	0.09	-0.31
(5)	-0.04	-0.12***	0.12*	-0.31***	-0.93***	-0.17	-0.05**	0.04	-0.02	-0.17***	0.21***	0.02	-0.02	-0.04**	0.16	0.25
(6)	-0.03	-0.17***	0.07	-0.25***	-0.16*	-0.97***	-0.05**	-0.15***	-0.18***	-0.17***	0.09	0.09***	-0.01	0.00	0.06	0.57
(7)	-0.03	-0.09**	-0.03	-0.21***	0.13*	0.14**	-0.54***	-0.01	-0.06	-0.16***	-0.16***	-0.04	0.11**	-0.04	0.26***	-0.18
(8)	0.08	-0.21***	-0.12	-0.20***	0.11*	-0.26**	-0.09***	-0.44	-0.02	-0.18***	-0.16	-0.07**	0.09	-0.01	-0.12	0.17
(9)	0.07	-0.14***	0.23**	-0.28***	0.05*	-0.32**	-0.10***	0.01	-0.30***	-0.17***	0.08	0.05	-0.02	-0.08***	0.24	-0.22
(10)	-0.10*	-0.12***	0.15*	-0.01	-0.06	-0.06	-0.06	-0.09	-0.04	-0.58***	0.11	0.10***	-0.10	0.10**	0.17	-0.11
(11)	-0.07*	-0.15***	0.10	-0.26***	0.24*	0.12**	-0.15***	-0.12	0.00	-0.15***	-0.95**	0.03	0.11**	0.01	-0.13	0.14
(12)	0.10*	-0.23***	-0.08	-0.17***	0.10	0.33	-0.11***	-0.10	0.03	-0.13***	0.11**	-0.90***	0.03	0.06	0.50***	-0.07
(13)	-0.20***	-0.07***	-0.10*	-0.27***	-0.03	0.00**	-0.05	0.05	-0.06	-0.18***	0.12	0.00	-0.43***	-0.07***	0.07	0.07
(14)	0.08**	-0.20***	-0.06	-0.19***	-0.05	0.06***	-0.10	0.00	-0.11	-0.13***	0.07	0.06**	-0.09**	-0.67***	0.12	0.06
(15)	-0.07***	-0.17***	0.11***	-0.27***	0.03	0.00***	-0.07	-0.05	-0.02	-0.16***	-0.06	0.04**	0.00	-0.02	-0.61***	-0.26
(16)	0.07	-0.13	0.20	-0.30	0.23	0.61	-0.15	0.07	-0.15	-0.18	0.10	-0.04	0.04	-0.01	-0.74	-0.93

******, **, * indicate significance at 1%, 5% and 10% respectively.***

Grains and grain-based products= (1); Vegetables and vegetable products= (2); Starchy roots, tubers, legumes, nuts and oilseeds = (3); Fruit and fruit products = (4); Beef, veal and lamb= (5); Pork =(6); Poultry, eggs, other fresh meat = (7); Processed meat products = (8); Fish and seafood =(9); Milk and dairy products= (10); Cheese =(11); Sugar and confectionary and prepared desserts =(12); Plant based fats= (13); Composite dishes =(14); Snacks and other foods =(15); Residual category =(16).

Appendix 4A

Series 1	Plan A	Plan B
1	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	6,8€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
2	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	7,5€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
3	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	8,3€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
4	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	9,3€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
5	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	10,6€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
6	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	12,5€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
7	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	15,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
8	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	18,5€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
9	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	22,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
10	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	30,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
11	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	40,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
12	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	60,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
13	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	100,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
14	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	170,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
	I choose Plan A for Questions 1-____	I choose Plan B for Questions___ -14
Series 2	**Plan A**	**Plan B**
15	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	5,4€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
16	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	5,6€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
17	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	5,8€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
18	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
19	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,2€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
20	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,5€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
21	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,8€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
22	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	7,2€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □

23	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	7,7€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
24	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	8,3€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
25	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	9,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
26	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	10,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
27	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	11,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
28	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	13,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
	I choose Plan A for Questions 15 - ____	I choose Plan B for Questions___ - 28
Series 3	Plan A	Plan B
29	Gain 2,5€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 2,1€ Yes □ □ □ □ □
30	Gain 0,4€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 2,1€ Yes □ □ □ □ □
31	Gain 0,1€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 2,1€ Yes □ □ □ □ □
32	Gain 0,1€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,6€ Yes □ □ □ □ □
33	Gain 0,1€ Yes □ □ □ □ □ Loss 0,8€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,6€ Yes □ □ □ □ □
34	Gain 0,1€ Yes □ □ □ □ □ Loss 0,8€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,4€ Yes □ □ □ □ □
35	Gain 0,1€ Yes □ □ □ □ □ Loss 0,8€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,1€ Yes □ □ □ □ □
	I choose Plan A for Questions 29 - ____	I choose Plan B for Questions___ - 35

Appendix 4B

	Plan A	Plan B
1	Receive 12€ in a week	Receive 2€ today
2	Receive 12€ in a week	Receive 4€ today
3	Receive 12€ in a week	Receive 6€ today
4	Receive 12€ in a week	Receive 8€ today
5	Receive 12€ in a week	Receive 10€ today
I choose Plan A for Questions1 until ___		I choose Plan B for Questions___ until 5
	Plan A	**Plan B**
6	Receive 12€ in a month	Receive 2€ today
7	Receive 12€ in a month	Receive 4€ today
8	Receive 12€ in a month	Receive 6€ today
9	Receive 12€ in a month	Receive 8€ today
10	Receive 12€ in a month	Receive 10€ today
I choose Plan A for Questions 6 until ___		I choose Plan B for Questions___ until 10
	Plan A	**Plan B**
11	Receive 12€ in 3 months	Receive 2€ today
12	Receive 12€ in 3 months	Receive 4€ today
13	Receive 12€ in 3 months	Receive 6€ today
14	Receive 12€ in 3 months	Receive 8€ today
15	Receive 12€ in 3 months	Receive 10€ today
I choose Plan A for Questions11 until___		I choose Plan B for Questions___ until 15
	Plan A	**Plan B**
16	Receive 30€ in a week	Receive 5€ today
17	Receive 30€ in a week	Receive 10€ today
18	Receive 30€ in a week	Receive 15€ today
19	Receive 30€ in a week	Receive 20€ today
20	Receive 30€ in a week	Receive 25€ today
I choose Plan A for Questions16 until___		I choose Plan B for Questions___ until 20
	Plan A	**Plan B**
21	Receive 30€ in a month	Receive 5€ today
22	Receive 30€ in a month	Receive 10€ today
23	Receive 30€ in a month	Receive 15€ today
24	Receive 30€ in a month	Receive 20€ today
25	Receive 30€ in a month	Receive 25€ today
I choose Plan A for Questions 21 until___		I choose Plan B for Questions___ until 25
	Plan A	**Plan B**
26	Receive 30€ in 3 months	Receive 5€ today
27	Receive 30€ in 3 months	Receive 10€ today
28	Receive 30€ in 3 months	Receive 15€ today
29	Receive 30€ in 3 months	Receive 20€ today
30	Receive 30€ in 3 months	Receive 25€ today
I choose Plan A for Questions 26 until ___		I choose Plan B for Questions___ until 30

	Plan A	Plan B
31	Receive 3€ in a week	Receive 0,5 today
32	Receive 3€ in a week	Receive 1€ today
33	Receive 3€ in a week	Receive 1,5€ today
34	Receive 3€ in a week	Receive 2€ today
35	Receive 3€ in a week	Receive 2,5€ today
I choose Plan A for Questions 31 until___		I choose Plan B for Questions___ until 35
	Plan A	**Plan B**
36	Receive 3€ in a month	Receive 0,5 today
37	Receive 3€ in a month	Receive 1€ today
38	Receive 3€ in a month	Receive 1,5€ today
39	Receive 3€ in a month	Receive 2€ today
40	Receive 3€ in a month	Receive 2,5€ today
I choose Plan A for Questions 36 until___		I choose Plan B for Questions___ until 40
	Plan A	**Plan B**
41	Receive 3€ in 3 months	Receive 0,5 today
42	Receive 3€ in 3 months	Receive 1€ today
43	Receive 3€ in 3 months	Receive 1,5€ today
44	Receive 3€ in 3 months	Receive 2€ today
45	Receive 3€ in 3 months	Receive 2,5€ today
I choose Plan A for Questions 41 until___		I choose Plan B for Questions___ until 45
	Plan A	**Plan B**
46	Receive 24€ in 3 days	Receive 4€ today
47	Receive 24€ in 3 days	Receive 8€ today
48	Receive 24€ in 3 days	Receive 12€ today
49	Receive 24€ in 3 days	Receive 16€ today
50	Receive 24€ in 3 days	Receive 20€ today
I choose Plan A for Questions 46 until___		I choose Plan B for Questions___ until 50
	Plan A	**Plan B**
51	Receive 24€ in 2 weeks	Receive 4€ today
52	Receive 24€ in 2 weeks	Receive 8€ today
53	Receive 24€ in 2 weeks	Receive 12€ today
54	Receive 24€ in 2 weeks	Receive 16€ today
55	Receive 24€ in 2 weeks	Receive 20€ today
I choose Plan A for Questions 51 until___		I choose Plan B for Questions___ until 55
	Plan A	**Plan B**
56	Receive 24€ in 2 months	Receive 4€ today
57	Receive 24€ in 2 months	Receive 8€ today
58	Receive 24€ in 2 months	Receive 12€ today
59	Receive 24€ in 2 months	Receive 16€ today
60	Receive 24€ in 2 months	Receive 20€ today
I choose Plan A for Questions 56 until___		I choose Plan B for Questions___ until 60

	Plan A	Plan B
61	Receive 6€ in 3 days	Receive 1€ today
62	Receive 6€ in 3 days	Receive 2€ today
63	Receive 6€ in 3 days	Receive 3€ today
64	Receive 6€ in 3 days	Receive 4€ today
65	Receive 6€ in 3 days	Receive 5€ today
I choose Plan A for Questions 61 until___		I choose Plan B for Questions___ until 65
	Plan A	**Plan B**
66	Receive 6€ in 2 weeks	Receive 1€ today
67	Receive 6€ in 2 weeks	Receive 2€ today
68	Receive 6€ in 2 weeks	Receive 3€ today
69	Receive 6€ in 2 weeks	Receive 4€ today
70	Receive 6€ in 2 weeks	Receive 5€ today
I choose Plan A for Questions 66 until___		I choose Plan B for Questions___ until 70
	Plan A	**Plan B**
71	Receive 6€ in 2 months	Receive 1€ today
72	Receive 6€ in 2 months	Receive 2€ today
73	Receive 6€ in 2 months	Receive 3€ today
74	Receive 6€ in 2 months	Receive 4€ today
75	Receive 6€ in 2 months	Receive 5€ today
I choose Plan A for Questions 71 until___		I choose Plan B for Questions___ until 75

Supplementary Appendix S.1. Measuring Beliefs and Attitudes towards Obese Persons

S.1.1 Scoring instructions for ATOP.

Step 1: Multiply the response to the following items by -1 (i.e., reverse the direction of scoring):

- Item 2 through Item 6, Item 10 through Item 12, Item 14 through Item 16, Item 19 and Item 20

Step 2: Add up the responses to all items.

Step 3: Add 60 to the value obtained in Step 2. This value is the ATOP score. Higher numbers indicate more positive attitudes.

S.1.2 Scoring instructions for BAOP.

Step 1: Multiply the response to the following items by -1 (i.e., reverse the direction of scoring):

- Item1, Items 3 through Item 6, Item 8

Step 2: Sum the responses to all items.

Step 3: Add 24 to the value obtained in Step 2. This value is the BAOP score. Higher numbers indicate a stronger belief that obesity is *not* under the obese person's control.

Appendix 5A.
Measuring Risk Attitudes: Risk and Loss Aversion

1. *Experiment design*

To elicit the three PT parameters (risk aversion - σ, loss aversion - λ, and non-linear probability weighting - γ), respondents were given three series of games that contained 35 pair-wise choices. **Table S1** shows the 3 series of games. Series 1 consists of 14 games. Series 2 consists of 14 games, and Series 3 consists of 7 games. In each game, the respondent is offered two plans: Plan A and Plan B. For instance, in Series 1, the first game shows that Plan A offers 30% of receiving 4 euros and 70% of receiving 1 euro, while Plan B offers 10% of receiving 6.8 euros and 90% of receiving 0.5 euros. Since there are 14 games, each respondent has to decide whether he or she prefers Plan A or Plan B for each row[36].

Following Tanaka et al. (2010), monotonicity was imposed on the respondents' choice decisions, indicating that if respondent *i* switches at row q for series 1, we conclude that he/she prefers Plan A over Plan B at row q-1 and prefers Plan B over Plan A at row q. Thus, each respondent had three options: a) choose Plan A throughout all games; b) choose Plan B throughout all games; and c) choosing Plan A for a certain number of games and then switch to Plan B for the rest. Individuals who are more averse to loss would choose Plan A a greater number of times over Plant B. Series 2 followed the same procedure as in Series 1. The loss aversion parameter is calculated using Series 3. Contrary to the previous two Series, here payoffs were made to be either positive or negative.

After the respondent completed the experiment, two bingo cages were used to determine the money that each respondent took home. The first bingo cage contained 35 numbered balls (indicating which row/question to play), while the second contained 10 numbered balls (indicating the probability). If ball number 10 was randomly selected from the first bingo cage, it means the subject would play row/question 10 out of the 35 questions. Once the question has been determined, a ball would be drawn from the 10 numbered balls in the second bingo and the selected question played according to the subject's plan. For instance, if the subject draws the ball number 2 from the second bingo and had previously chosen Plan A, he or she would have earned 4 Euro (or 0.5 Euro if the respondent had chosen Plan B).

1. *Estimating parameters*

The switching points from series 1 and series 2 are used to estimate the curvature of the utility function (risk aversion) and the nonlinear probability weighting parameter (not applicable in

[36] The maximum amount offered in Plan B was 170€, equivalent to the regulated minimum salary for one week.

this study) of each participant. Calculated parameter estimates[37] of risk aversion and probability weighting for different combinations of the switching points in series 1 and series 2 are shown in **Table S.2** and **Table S.3**, respectively. For instance, from **Table S.2**, if the respondent switched at game 5 in series 1 and game 3 in series 2, then the corresponding risk aversion parameter is 1.0, indicating risk neutral. Also, for the probability weighting parameter, if the respondent switched at game 5 in series 1 and game 3 in series 2, then the corresponding risk aversion parameter is 0.8, indicating overweighting of low probabilities.

After obtaining the risk aversion and probability weighting parameters from both series 1 and series 2, we can estimate the loss aversion parameter using the switching points in series 3. This was achieved by writing out an inequality for the switiching points of series 3 and introducing the risk parameter into the equation 1(see Liu and Huang, 2013).

[37]Example when a respondent switch from Option A to B at the fifth questions in Series 1 and at the third question in series 2, the following inequalities should hold. Average estimates are on Table 2 and Table 3.

$4^{\sigma}\exp[-(-\ln .3)^{\alpha}]+1^{\sigma}\exp[-(-\ln .7)^{\alpha}]>9.3^{\sigma}\exp[-(-\ln .1)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln .9)^{\alpha}]$,

$4^{\sigma}\exp[-(-\ln .3)^{\alpha}]+1^{\sigma}\exp[-(-\ln .7)^{\alpha}]<10.6^{\sigma}\exp[-(-\ln .1)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln .9)^{\alpha}]$,

$4^{\sigma}\exp[-(-\ln .9)^{\alpha}]+3^{\sigma}\exp[-(-\ln .1)^{\alpha}]>5.6^{\sigma}\exp[-(-\ln .7)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln .3)^{\alpha}]$,

$4^{\sigma}\exp[-(-\ln .9)^{\alpha}]+3^{\sigma}\exp[-(-\ln .1)^{\alpha}]<5.8^{\sigma}\exp[-(-\ln .7)^{\alpha}]+0.5^{\sigma}\exp[-(-\ln .3)^{\alpha}]$.

Appendix 4B

Experimental Lotteries to Risk attitudes

Series 1	Plan A	Plan B
1	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	6,8€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
2	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	7,5€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
3	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	8,3€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
4	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	9,3€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
5	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	10,6€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
6	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	12,5€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
7	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	15,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
8	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	18,5€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
9	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	22,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
10	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	30,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
11	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	40,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
12	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	60,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
13	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	100,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
14	4€ Yes □ □ □ 1€ Yes □ □ □ □ □ □ □	170,0€ Yes □ 0,5€ Yes □ □ □ □ □ □ □ □ □
	I choose Plan A for Questions 1- ____	I choose Plan B for Questions___ -14
Series 2	Plan A	Plan B
15	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	5,4€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
16	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	5,6€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
17	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	5,8€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
18	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
19	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,2€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
20	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,5€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
21	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	6,8€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □

22	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	7,2€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
23	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	7,7€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
24	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	8,3€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
25	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	9,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
26	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	10,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
27	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	11,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
28	4€ Yes □ □ □ □ □ □ □ □ □ 3€ Yes □	13,0€ Yes □ □ □ □ □ □ □ 0,5€ Yes □ □ □
	I choose Plan A for Questions 15 - ____	I choose Plan B for Questions___ - 28
Series 3	Plan A	Plan B
29	Gain 2,5€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 2,1€ Yes □ □ □ □ □
30	Gain 0,4€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 2,1€ Yes □ □ □ □ □
31	Gain 0,1€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 2,1€ Yes □ □ □ □ □
32	Gain 0,1€ Yes □ □ □ □ □ Loss 0,4€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,6€ Yes □ □ □ □ □
33	Gain 0,1€ Yes □ □ □ □ □ Loss 0,8€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,6€ Yes □ □ □ □ □
34	Gain 0,1€ Yes □ □ □ □ □ Loss 0,8€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,4€ Yes □ □ □ □ □
35	Gain 0,1€ Yes □ □ □ □ □ Loss 0,8€ Yes □ □ □ □ □	Gain 3,0€ Yes □ □ □ □ □ Loss 1,1€ Yes □ □ □ □ □
	I choose Plan A for Questions 29 - ____	I choose Plan B for Questions___ - 35

Appendix 5C

Switching point (question) in Series 1 and 2, and approximations of σ (parameter for the curvature of power value function/risk parameter)

σ	Switching point for series 1													
Series 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Never
1	1.50	1.40	1.35	1.25	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.65	0.55	0.50
2	1.40	1.30	1.25	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.60	0.55	0.50
3	1.30	1.20	1.15	1.10	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45
4	1.20	1.15	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45	0.40
5	1.15	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.55	0.50	0.45	0.40	0.35
6	1.05	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35
7	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30
8	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25
9	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20
10	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.20
11	0.80	0.70	0.65	0.60	0.65	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.15
12	0.75	0.65	0.60	0.55	0.50	0.50	0.45	0.40	0.35	0.30	0.25	0.20	0.20	0.15	0.10
13	0.65	0.60	0.55	0.50	0.45	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.15	0.10	0.10
14	0.60	0.55	0.50	0.45	0.40	0.35	0.35	0.30	0.25	0.20	0.15	0.10	0.10	0.10	0.05
Never	0.50	0.45	0.40	0.40	0.35	0.30	0.30	0.25	0.20	0.15	0.10	0.10	0.05	0.05	0.05

Appendix 5D

Switching point (question) in Series 1 and 2, and α (probability sensitivity parameter in Prelec's weighting function

α	**Switching question in series 1**														
Series 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Never
1	0.60	0.75	0.75	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.40	1.45
2	0.60	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.35	1.40
3	0.55	0.60	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30
4	0.50	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25
5	0.45	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20
6	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15
7	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10
8	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05
9	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
10	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
11	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
12	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
13	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
14	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
Never	0.05	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.45	0.55	0.55	0.65	0.60