

Consumer health

December 2022

True pricing method for agri-food products



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Impact-specific module for true price assessment

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This document provides the consumer health module for the assessment of the true price of an agricultural product, within the PPS 'Echte en Eerlijke prijs' developed by True Price and Wageningen Economic Research. It provides information on quantification and monetisation of these impacts and it is meant to be used in combination with the **True Pricing Assessment Method for Agri-food Products** (Galgani et al., 2021a). The **Valuation Framework for True Price Assessment of Agri-food Products** explains the underlying framework (Galgani et al., 2021b). Both these documents are developed within the same project.

Authors:

Behrang Manouchehrabadi¹

Bart van Veen²

Pietro Galgani^{2,3}

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¹ Wageningen Economic Research, Pr. Beatrixlaan 582 - 528, 2595 BM Den Haag, <https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/Economic-Research.htm>

² True Price, Haarlemmerplein 2, 1013 HS Amsterdam, www.trueprice.org

³ Corresponding author: pietro@trueprice.org

⁴ For more information on the PPS *True and Fair Price for Sustainable Products*, please refer to <https://www.wur.nl/nl/project/Echte-en-eerlijke-prijs-voor-duurzame-producten.htm>

Documents of the true price methodology for agri-food products

This **Consumer health - Impact-specific module for true price assessment** was developed by Wageningen Economic Research and True Price within the PPS True and Fair Price for Sustainable Products.

This document contains the key methodological aspects to measure and value one impact of agri-food products and value chains: consumer health in relation to diets.

This impact-specific module is complemented by four **Social and human capital modules** and six **Natural capital modules**. The other social capital modules are: 1) Occupational health and safety; 2) Animal welfare; 3) Living income gap; 4) Child labour. These impact-specific modules are preceded by the **Valuation framework for true pricing of agri-food products** (Galvani et al., 2021a), which contains the theoretical framework, normative foundations and valuation guidelines, and the **Assessment Method for True Pricing of Agri-Food products** (Galvani et al., forthcoming), which contains modelling guidance and requirements for scoping, data and reporting (Figure 1).

Together, these documents present a method that can be used for true pricing of agri-food products, and potentially other products as well.

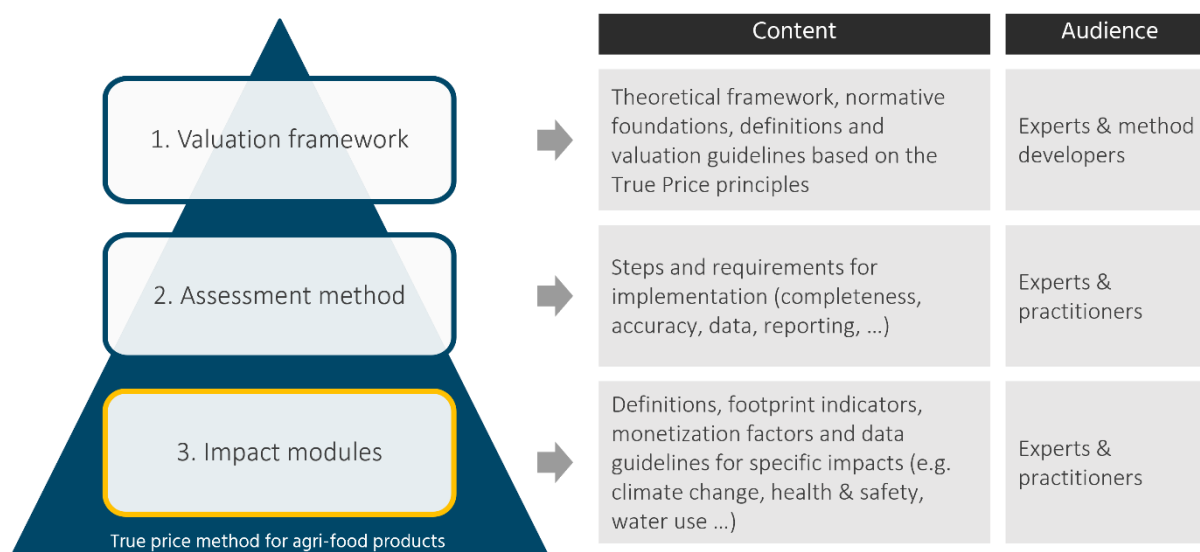


Figure 1. Components of the true price methodology for agri-food products. This document is one of the impact modules.

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1. Introduction

This document provides a method module for the assessment of the true price of food products, within the public-private partnership 'Echte en Eerlijke Prijs' by Wageningen Economic Research, True Price and Bionext. It contains the key methodological aspects to measure and value one impact of agri-food products: negative effects on consumer health by diets.

This module can be used together with the **True Pricing Assessment Method for Agri-food Products** (Galgani et al., forthcoming).

This document consists of 5 Sections. This section is an introduction. Section 2 provides definitions. Section 3 discusses the rationale for including these impacts in a true price assessment and discusses to what extent the externality should be included in a true price. Section 4 discusses the modelling approach. Finally, Section 5, provides an overview of limitations and key items for further research.

2. Definitions

The Valuation Framework for True Price Assessment of Agri-food Products provides a list of impacts to be considered in the true price (Galgani et al., 2021). The 'Negative effects on consumer health and safety' are listed as one of the social impacts. This module covers the negative health effects of the consumption of food specifically, considering the following definition of the impact 'Consumer Health':⁵

- The negative externalities, related to consumer health, of the human consumption of a food product within a certain diet.

The potential positive health effects of food consumption are not considered in this method for two reasons. The first reason is specific to this module. This module takes an optimal diet as a reference and therewith assumes that all nutritional requirements are met (see Section 4.2). The second reason relates to the general concept of true price. Dietary benefits should, as well as other positive effects, be included in a separate metric alongside the true price, such as the true value, to prevent netting of positive and negative effects (Galgani et al., 2021a).

The definition includes externalities explicitly, because not all negative health-related effects of food consumption are externalities. The Valuation Framework defines an externality as 'a societal cost or benefit that affects a party who did not choose to incur this cost or benefit'. Section 3.2 provides a more detailed discussion on which negative effects are externalities in this context and should therefore be included in the true price of a product.

This method only includes the negative effects of human consumption. The negative effects of food production on human health are included in other impacts, such as human toxicity in air, soil and water pollution (Galgani et al., 2021b).

The effect of the consumption of a food product depends on the diet that the product is a part of. Within true pricing, a healthy diet serves as the reference to assess the effects of consumption of a food product

⁵ The potential negative health and safety effects from other uses of the product by the consumer, such as meal preparation, are not included in the scope of this module.

on the health of the consumer. The following definitions related to a healthy diet are used (Neufeld et al., 2021):

- **Diets** are the combinations of foods consumed by individuals over a given time.
- A **healthy diet** is health-promoting and disease-preventing. It provides adequacy without excess, of nutrients and health-promoting substances from nutritious foods and avoids the consumption of health-harming substances.

Foods that make up a healthy diet should both be nutritious and safe.⁶ The negative health effects of the nutritious value of a food product are included in the scope of this module, while the safety aspects are not in scope.

- A **nutritious food** is a food that, in the context where it is consumed and by the individual that consumes it, provides beneficial nutrients (e.g., protein, vitamins, minerals, essential amino acids, essential fatty acids, dietary fibre) and minimises potentially harmful elements (e.g., anti-nutrients, quantities of sodium, saturated fats, sugars).⁷

3. Background and rationale for including as part of the true price

3.1. Unhealthy diets are an important societal problem

In 2017, the global number of annual, diet-related deaths was estimated at 11 million. The Global Burden of Disease (GBD) of dietary risks was estimated to be 255 million life years lost due to ill health, disability or early death, expressed as Disability-Adjusted Life Years (DALYs) (Afshin et al., 2019). Disability, illness, or early death do not only cause reductions in well-being, but also cause increases in healthcare expenditures and losses of economic productivity. In 2013, the United Nations Food and Agriculture Organisation (FAO) estimated the cost of malnutrition to the global economy at US\$ 3.5 trillion per year, or US\$ 500 per person per year (FAO, 2013).

FAO (2017) discussed the different pathways through which food affects health: hunger and malnutrition, unhealthy diets, low quality food, agri-environmental risks, occupational hazards, and exposure to agricultural inputs. The focus of this module is on the effects of sub-optimal intake of certain food types. A sub-optimal intake can refer to either an overconsumption or an underconsumption of certain food types or nutrients compared to the reference intake of that food type in an optimal diet. The previously mentioned GBD study attributed half of diet-related deaths and two-thirds of diet-related DALYs to high intake of sodium, low intake of whole grains, and low intake of fruits (Afshin et al., 2019). According to Schwingshackl et al. (2019),

'The largest estimated DALYs were associated with suboptimal intakes of whole grains (10%), followed by nuts (7.1%), processed meat (6.4%), fruits (4.4%), fish (4.2%), legumes (4.2%), and SSB (3.9%).'

⁶ A safe food is a food that does not increase the probability of poor health outcomes when part of a broader recommended diet in the context where it is consumed. Specifically, safe food is that in which attributes derived from the value chain (pathogens, parasites and contaminants, including agrochemicals and food chain mycotoxins) that could cause adverse health outcomes do not exceed internationally agreed thresholds (GAIN, 2017).

⁷ gain-nutritious-food-definition.pdf (gainhealth.org).

for 16 European countries.⁸ It is important to note that in the study of Schwingshackl et al. (2019), suboptimal intakes referred to the underconsumption of whole grains, nuts, fruits, fish and legumes and the overconsumption of processed meat and sugar sweetened beverages in average diets with respect to an optimal diet.

A study by FAO emphasised the importance of the intake of ultra-processed foods (FAO 2019):

'Taken together, the results from the studies on diet quality show significant and graded associations between the dietary share of ultra-processed foods and dietary nutrient profiles prone to non-communicable diseases, including high or excessive content of free or added sugar, saturated and trans fats, and sodium, and also high dietary energy density; and low or insufficient content of protein, fibre and potassium.'

Carbonated soft drinks, sweet and savoury snacks, biscuits, confectionary and cakes, pastries and deserts are especially problematic. An important problem is that ultra-processed foods are cheap to produce and aggressively marketed, resulting in excessive consumption of them at the cost of healthy less-processed foods.

3.2. Why the health-related negative effects of food consumption should be included in the true price gap

Even though the effects of diets on health have been estimated to be large, this does not logically imply that these effects should also be included in the true price of a product. The Valuation Framework⁹ defines social impacts that should be included in the true price as:

'Impacts on people and communities caused by production and consumption. In the context of a true price gap assessment, social impacts are unsustainable externalities related to breaches of human rights and labour rights.'

The definition specifies that for an impact to be included in the true price gap, it should 1) be related to breaches of basic rights and 2) be an externality.

3.2.1. The relation between negative health-related effects of food consumption and breaches of basic rights

In the case of 'negative effects on consumer health', the right to an adequate standard of living is relevant as everyone should have access to healthy food:

'Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, ...' - UN Universal Declaration of Human Rights, article 25.1.

However, the right to freedom can be interpreted as the right to choose to eat unhealthy products:

'Everyone has the right to life, liberty and security of person.' - UN Universal Declaration of Human Rights, article 3.

⁸ SSB stands for sugar sweetened beverages.

⁹ The valuation framework provides the normative foundation of which effects of a product should and which should not be included in the true price gap.

For example, no generally accepted rights of the consumer are violated if the consumer consciously chooses to consume an unhealthy diet (i.e., the foods required for an adequate standard of living in terms of health and well-being are available, affordable and known to the consumer). However, the mentioned rights of other people can also be affected by the consumer's choice to consume an unhealthy diet. Also, one can argue whether consumers consciously choose to purchase food products that are likely to contribute to an unhealthy diet (Cohen and Babey, 2012). Ultimately, whether the effect is an externality determines if it should be included in the true price gap of a product.

3.2.2. Negative health-related effects of food consumption that are an externality

Consumers play an active role in the lifecycle of a product. One can argue that this role is a conscious choice of the consumer and that therefore its effects are internalities. If so, the health-related costs of consumption should not be included in the true price of a food product. However, not only the consumer itself, but society-at-large also bears the costs of the consumer's choice.

3.2.2.1. Negative externality included in the module

The current module includes one negative, health-related externality of food consumption: healthcare costs to society. The following paragraph specifies what this effect is and why it should be included in the true price gap of a product.

Healthcare costs to society

A reduced health of a consumer leads to an increase in healthcare costs. These costs are (partly) borne by society through a social healthcare system. Society did not choose to incur the increased costs of a specific group of people if these healthcare costs could have been reasonably prevented with the consumption of a healthy diet. Therefore, these costs should be included in the true price of a food product and fall within the scope of this module.

3.2.2.2. Negative effects not included in the module

The following paragraphs list different negative, health-related effects of food consumption that are not included in the current module. Each paragraph specifies: 1) what the effect is, 2) why it should or should not be included in the true price gap of a product, and 3) why it is not included in the current module.

Wellbeing effects to consumers

Consumption of an unhealthy diet affects the health of a consumer, which ultimately affects different forms of consumer wellbeing (such as psychological, financial, or other forms). As mentioned before, negative effects should only be included in the true price if these effects are externalities and one could argue that every consumer has a free choice in consuming a food product. In the idealistic case of a free market this might be true. In reality, it is less straightforward to determine whether the consumption of a product is a choice. Many contextual aspects might cause a consumer to consume an unhealthy diet. These causes determine whether the health (and ultimately the related wellbeing effects) should be considered an externality or not.

A fully informed, fully rational, and independent, wealthy consumer has a free choice to consume a product or not. However, the following scenarios question whether the consumption of a specific product is always a free choice. Is the consumption of an unhealthy product a choice when you are not well informed on its future or potential negative effects? On the one hand, it is the consumer's responsibility to know what a healthy product or diet is. But on the other hand, how transparent and understandable the available information is, might lower the consumer's responsibility. Additionally, one might question how much the market influences consumer behaviour sub-consciously. Furthermore, is the consumption of a specific product a choice if the consumer does not have the budget to buy a healthy alternative, or no healthy alternative is available? Is the consumption of a product a choice for children who eat what their parents

feed them? The following is potentially an exceptional situation, but still relevant: do you consider the consumption of a product a choice if the consumer is addicted to certain substances, such as cigarettes, alcohol or even sugar?

The above shows the complexity when determining if the wellbeing effect of food consumption on the consumer is an externality. In specific situations one can argue that the effects should be included in the true price, while in other situations the same effects should not be included. Given this complexity, these effects are not included in the current module.

Productivity loss

A reduced health might lead to absenteeism at work. The income loss due to absenteeism is a negative effect for the consumer. Absenteeism also leads to economic costs for employers (both businesses and organisations), such as social security costs and a reduction in the available workforce.

The complexity of determining whether the effect on consumers is an externality, as specified for wellbeing effects, also holds for income loss for consumers. Therefore, this effect is not included in this module. The economic costs for employers are an externality and should ideally be included in the true price. However, it is not included in this module due to a lack of available information on reasons for absence.

Negative health effects due to unsafe food

Food safety largely depends on the treatment of a food product by different actors throughout its lifecycle, including food preparation at the consumer phase. Unsafe food can negatively affect consumer health through, for example, micro-organisms or chemical contamination. Depending on their cause, these effects can be considered an externality. For example, on the one hand, the negative effects on consumer health following from an industrial food processor disregarding food safety regulation are considered externalities. While on the other hand, incorrect treatment of a food product by the consumer could be considered to not be an externality. Ideally, externalities due to unsafe food affecting consumer health should be considered in the true price, but are out of scope of the current module. This module focuses solely on the health effects from the nutritional value of food.

Occupational safety is the extent to which working can lead to fatal and non-fatal injuries and is therefore not included in the impact 'Consumer Health' but should be included in 'Occupational Health and Safety'.

3.2.3. How are the negative health-related effects of food consumption considered in the true price?

In addition to whether it is a free choice or not to consume a food product, how this product fits in the overall diet of the consumer adds a level of complexity. Negative effects on health cannot be attributed to the product itself but ultimately depend on the diet that the product is a part of. For example, the WHO provides reference intakes for energy and nutrition, and their relation to specific food products, beyond or below which health might be negatively affected.¹⁰ True pricing examines externalities of products when they are bought, which makes it difficult to assess what the choices available to the person buying and/or consuming the product are and what his/her diet is.

However, it is at least possible to simplify by assuming that the products are bought by the average consumer with respect to a healthy diet. How nutritious a food product is (i.e., how it contributes to a healthy diet) can be considered a reflection of the effect a food product has on consumer health. This includes both the over- and underconsumption of ingredients that form a healthy diet.

¹⁰ <https://www.who.int/news-room/fact-sheets/detail/healthy-diet>

In summary, the externalities of the increased healthcare costs (a cost to society, following Section 3.2.2) as a result of the over- and underconsumption of food types compared to a healthy diet (following Section 3.2.3), are included in this module. The following sections provide further details on the modelling approach, the quantification and monetisation of these costs.

4. Modelling approach

4.1. Introduction

This section presents the methodology of defining, quantifying and monetising the health impact of food consumption. This is done in four consecutive steps as shown in Figure 4.1. The first three steps require both a conceptual decision making and also a measurement protocol for quantification. The conceptual decision making of the first three steps are explained in the rest of this chapter. Quantification is discussed in Chapter 5 and monetisation is presented in Chapter 6.

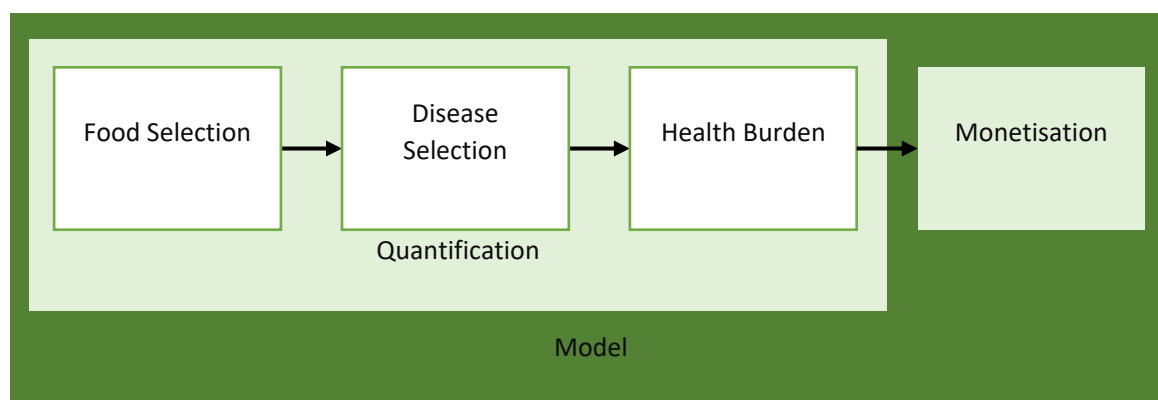


Figure 4.1 Modelling approach

4.2. Food selection

Product definition and selection is an early step of a true price assessment, which is covered in the *Assessment Method for True Pricing of Agri-Food products*. There are, however, two points to address regarding the food products.

First, most food products consist of various ingredients (and contain a large number of nutrients). Some of these ingredients might have health benefits while the others might be harmful. As a result, estimating the total effect of consuming the food requires netting off the negative effects of harmful ingredient from the beneficial effects of the nutrients. For example, chocolate consists of both cocoa and sugar. Cocoa is considered to be an ingredient with positive health effects but sugar is not. Our approach in such cases is to focus on the harmful ingredients because the reference point is defined to be the optimal diet. An optimal diet, by definition, contains all beneficial nutrients in the sufficient amount. Second, for some food categories, there are standards or consensual definitions on the foods that belong to the categories, e.g., vegetables. For others, the definitions are more arbitrary and depends on the context. A prime example is processed foods. FAO uses the classification NOVA where foods are classified in four groups according to the level of processing. This classification, however, has been criticised by some studies. For instance, Petrus et al. (2021) argue that NOVA classification does not consider the level of processing but considers the quantity of ingredients. The classification of processed foods is in general a controversial issue and

there is no standard or widespread agreement about it (Sadler et al., 2021). In cases such as this where there is no accepted definition, the practitioners need to motivate their choice. The motivation can state the health importance, production consequences, and practical data limitations that leads them to focus on particular foods or opt for a particular definition.

4.3. Disease selection

The choice of diseases to include in the model is more straightforward, compared to food selection, as the problems with definition and classification appear much less. In addition, the contraction of a specific type of disease is more or less a binary outcome, i.e., one either has the disease or not.¹¹

Most food products or categories of food products are known to be associated with a disease or group of diseases. As a result, disease selection in itself is not an arduous task. There are, however, times when there is a need to make a selection among a group of diseases for various reasons due to time constraint, significance or other considerations. If this the case, then the following criteria can help. First, the significance of the diseases, the effect on public health or/and economic burden. Second, the availability of studies. The first criterion concerns the burden of a disease for the healthcare system and/or their economic implications. Some diseases require heavy usage of health care equipment, multiple visits and long hospitalisation. Other diseases might not, but they might impose a heavy burden on the employability of people and/or significantly reduce their well-being. The second criterion is a practical concern and results from the fact that some diseases are under-researched and so, relevant data might not exist or be publicly available. The Global Burden of Disease database¹² shows a number of diseases related to food consumption. It includes categories of diseases including heart diseases (coronary heart diseases, stroke, etc.), diabetes, gastrointestinal diseases, musculoskeletal, dermatological and phycological diseases among others.

4.4. Health burden

After selecting the food and the corresponding disease or diseases, one needs to search for scientific articles that study the relationship between food consumption and disease(s) contraction. Importantly, relying on a single or a couple of studies does not result in obtaining reliable results. It is needed to find a large number of comparable studies to have reliable results. By comparable, we mean studies that are similar in terms of research design, i.e., the choice of variables and the measurement protocols.

After finding comparable studies, they should be to synthesised in a systematic way. The proper technique for doing so is meta-analysis. Meta-analysis is a statistical analysis that synthesises the effect sizes of multiple independent studies (Greenlands and Rourke, 2008). It provides a pooled estimate for the unknown effect size by combining the reported effect sizes of individual studies. In doing so, individual studies are assigned a weight and then the weighted average of the effect sizes is considered as the combined effect size. The determination of the weights depends on the statistical method but it is generally a function of the inverse variance of the estimate. Therefore larger studies, which have lower variances, are given higher weights. Meta-analysis, when used correctly, provides a reliable picture of the relationship between food consumption and disease(s).

¹¹ There are of course grey areas where one cannot be assigned, with certainty, to the group of people having a specific type of disease. In most cases, however, people can be said, with some degrees of confidence, to fall in the categories of having or not having a disease.

¹² <https://vizhub.healthdata.org/gbd-compare/>

5. Quantification

5.1. The Link between food products and ingredient consumption

Recall that the aim of the module is to assess the health impact of food products and monetising it. The first step in doing so is relating the consumption of the ingredients to the food products. The consumption can be measured in terms of weight, standard servings, or deviation from the recommended consumption level. In food science, consumption is mostly measured not in isolation but as part of the diet and compared to the recommended consumption level. For example, consider sugar. Measuring sugar consumption involves measuring the amount of sugar in the diet and then comparing it with the recommended consumption level. If the diet contains more sugar than the recommended level, then the diet is categorised as a diet high in sugar. Otherwise, the diet is considered as a healthy diet in terms of sugar content. For beneficial foods, such as legumes, the diet is considered healthy in case its food content is equal or higher than the recommended level and low otherwise.

Relying on the optimal diet as the reference for consumption requires calculating the contribution of individual products to the total overconsumption of harmful ingredient of interest in the diet. As an example, consider the case of sugar and a chocolate bar. To know how the consumption of the chocolate bar affects total sugar overconsumption, it is needed to measure how the consumption of the chocolate bar affects the marginal overconsumption of sugar.

To solve this issue, an indicator is introduced that shows the contribution of a food product to the overall overconsumption of harmful ingredients. That is, we would like to have a measure that indicates the average daily/weekly consumption of the ingredient that can be attributed to the consumption of one unit of the food product. Sometimes such a measure is directly available, for example, in the case of processed meat. Other times, it might not readily be available and we need to estimate it. Below we proceed with introducing a measure to address this issue.

Denote the measure by C_r . If the food product and the ingredient of interest are the same, i.e., in case of meat, then set C_r equal to one. Otherwise proceed with the following steps to estimate it.

Step 1: Define daily intake as the reference rate for consumption.

Step 2: Obtain the maximum recommended daily consumption level of the ingredient. Denote it by M . Obtain the average daily consumption of the ingredient in the society and denote it by \bar{C} . The difference between these two values represents the average overconsumption in the society, denote it by \bar{O} . That is, $\bar{O} = \bar{C} - M$. If M is larger than \bar{C} , i.e., there is no overconsumption, then set $\bar{O} = M$.

Step 3: Estimate the average days it takes to consume one unit of product by one consumer (Denote it by T). If T is less than 1, then set it equal to 1. Otherwise, take the value that is obtained. For example, if it takes two days to eat a bar of chocolate on average, then $T = 2$.

Step 4: Obtain the amount of the ingredient in the food product. For example, the sugar content of a chocolate bar, salt in processed meat. If the food product itself is considered, then take the average weight of the unit of product. Denote it by W .

Step 5: Estimate the probability of consuming the food product in the diet of the average consumer of the product. For example, what is likelihood of eating a chocolate bar per day for the average consumer of chocolate. Denote it by p .

Step 6: use the following formula to obtain the contribution of the food product to the overconsumption of the ingredient of the interest.

$$C_r = \frac{W}{\bar{O} \times T} \times p$$

If $C_r > 1$, then set it equal to 1. Note that C_r is unitless as the numerator and the denominator both have the same unit, consumption rate. To illustrate, consider a chocolate bar that contains 50 grams of sugar, $W=50$. Note that the recommended maximum daily intake of sugar is around 30 grams (25 for women, 35 for men), so $M=30$. Assume the chocolate bar is usually consumed in a less than a day ($T=1$) and also the probability (p) that an average consumer, who consumes chocolate, buys that the chocolate bar is 0.5. Finally, the average daily intake of sugar is 20 gram. From step 2 we see that the average consumption is below the recommended consumption level, so $\bar{O} = M$. The above formula then implies

$$C_r = \frac{50}{1 \times 30} \times 0.5 = 0.83$$

That is, the marginal contribution of the chocolate bar to the daily sugar overconsumption is 0.83. Note that if the average consumer consumes the product on the daily basis, i.e., $p = 1$, then the above formula gives $C_r = 1$. In words, a chocolate bar that contains 50 grams of sugar and is consumed daily, fully contributes to overconsumption of sugar.

This contribution factor will be used later in the calculation of footprint indicator.

5.2. Quantifying the likelihood of disease contraction

In medical science, relative risk ratio (RR) or odds ratio are commonly used as the measure for the likelihood of developing diseases. These are measures that show the likelihood or chance of occurrence of an event, developing a disease in our case, as a result of exposure to a harmful substance. The following resources provide more information on the topic. (C.J.L. Murray et al., 2003; C.J. Murray et al., 2012; C.J.L. Murray et al. 2020) and C.J.L. Murray et al. (2020). Due to prevalence and relevance, we recommend and use relative risk (RR) as the measure for the likelihood of developing diseases. The Global Burden of Disease¹³ provides meta-analyses of relative risk for a number of diseases related to dietary risks.

Next, we need to estimate the relative risk per unit of consumption. This is necessary because the relative risk that is reported in most medical studies, including the GBD, indicates the association between (over)consumption over a long period of time and the development of diseases. We, however, need to estimate the relative risk associated with a unit of (over)consumption, i.e., the marginal relative risk. We do this in two steps.

Step 1: Estimate the long term overconsumption of the product (or ingredient) and denote it by LC. By long-term overconsumption, we mean the difference between the recommended consumption level and the actual consumption level over a period of 5 to 20 years. Studies that report the effect of (over)consumption on health outcomes usually monitor people over decades. Therefore, the reported relative risks reflect the effect of (over)consumption in the long term. We need to make sure that this point is taken into account in our calculations. We use the GBD for the recommended consumption level because relative risk is also taken from this source. The actual consumption level can be taken from various public and private institutions, depending on the country of the interest. Finally, note that we need to choose a

¹³ <https://vizhub.healthdata.org/gbd-compare>

unit for the long term overconsumption. Most studies define daily or weekly overconsumption in terms of one gram or 100 grams. For long-term overconsumption, however, kilogram seems to be a better unit.

Step 2: Assume that the effect of consumption (overconsumption) on the likelihood of diseases development is linear, see Chan et al. (2011) for the case of meat. Denote the marginal relative risk by MRR. Linear effect of overconsumption implies that

$$RR = (MRR)^{LC}$$

Therefore use the following formula to obtain the relative risk per unit.

$$MRR = \exp\left(\frac{\ln(RR)}{LC}\right)$$

Before going to the next part, it is worth explaining a critical methodological issue regarding association measures such as risk ratio and odd ratio. Most of the existing studies in food science rely on observational data, directly or indirectly, and report associations between food consumption and the prevalence of certain types of diseases. That is, these studies run surveys to measure food consumption and health status of individuals who agree to share their dietary and health information. Though these studies might differ in terms of design and research strategy, they more or less follow the same pattern. They consider overconsumption of a group of foods as a risk factor and estimate the effect of the overconsumption by comparing the health status, in terms of specific disease, between two or more groups of people whose diet contains different amounts of the food under consideration. The majority of these studies clearly state that they provide an association between food consumption and diseases. It is well known that an association might or might not imply a causal relationship. However, there still is a widespread malpractice of equating association with causation among researchers and practitioners. Therefore, it is important to explain and warn the readers before presenting the methodology. One major concern in identifying causal relationships from observational data is misidentifying association as causation. The ideal way to identify a causal relationship is running experiments. Suppose one is interested in the causal relationship between sugar consumption and obesity. It is needed to run an experiment in which a representative sample of population are randomly assigned to a control group and the treatment group. Then the sugar consumption in the treatment group is manipulated and, finally, the health status of the control and treatment group are compared. Doing this type of experiment, however, is not possible in social and natural settings including food science. There are various institutional, legal, and ethical barriers that prohibit undertaking such experiments. The second best method to identify causality is causal inference methods. These methods are sometimes called quasi-experimental methods as they mimic experiments to identify and measure causal relationships (Athey and Imbens, 2017). The causal inference methods are different depending on the context and availability of data. However, they share the common purpose of disentangling the effects of confounders and measuring the effect of the treatment. Though the applied causal inference methods are less demanding than experiments, they still require the existence of specific types of data that satisfy certain requirements. Unfortunately, the existing data do not always satisfy the requirements and so, these methods are not always applicable. Absent experimental evidence and causal inference studies, we have to rely on studies that are mostly report associations. Most studies in epidemiology, psychology and healthcare provide associations. This is not problematic unless the associations are understood and interpreted as causal evidence which is, unfortunately, a common practice. Needless to say, an association might actually imply a causal relationship. However, it should not be taken for granted, especially when these associations are used to inform policy measures. In the food health domain, the majority of studies are observational studies, establishing correlations between food consumption and various types of diseases and then another correlation between diseases and some measures of health status. As mentioned before, interpreting these results require careful attention to the fact that correlations do not necessarily imply causation.

5.3. Footprint indicator

The definition of relative risk implies that absent overconsumption (the counterfactual scenario), there would be $1/RRM$ incidence of the disease for each realised incidence. Therefore, the marginal contribution of overconsumption to an incidence of disease can be estimated by $(1-1/MRR)$. This is also equal to population attributable factor (PAF) that is frequently used in other sources (given that the exposure fraction is considered to be 1). Recall, from Section 5.1, that we denoted the marginal contribution of food consumption to the intake rate of an ingredient by C_r . Define the footprint indicator FPI as

$$FPI = \left(1 - \frac{1}{MRR}\right) \times C_r$$

Footprint indicator can be interpreted, roughly speaking, as the reduction in the likelihood of developing a disease under the counterfactual scenario of having consumed one less unit of the food product. Note that likelihood or probability is unitless and recall that C_r is also unitless. So, FPI is unitless too. We can, however, think of FPI as having likelihood per unit of food consumption as its informal unit.

6. Monetisation

Recall from Section 3 that the aim of this module is to provide a methodology to calculate the externalities of health impacts resulting from food consumption. The focus on externalities implies that the economic value of the health impacts of food consumption for the consumer is out of scope. Instead, the economic implications of food consumption for the society is the focus of the module. This is important because health care systems in most countries are financed completely or partially by the public. As a result, food consumption by consumers has implications for the whole society and not just for the consumers themselves. Given this consideration, Cost of Illness, limited to healthcare costs, is used as the method for monetisation and explained it below.

Costs of Illness (COI), aims to estimate the costs of a specific illness, for a specific country in a certain period, by estimating the direct healthcare costs, plus indirect costs, such as legal costs, transportation costs, and then adding them to the productivity loss (Jefferson et al., 2000). As far as externality is concerned, the direct healthcare costs is more relevant especially in countries with public healthcare system, such as the Netherlands and most OECD countries. As a result, direct health care costs of diseases is used. In the Netherlands, the National Institute for Public Health and Environment (RIVM) estimates direct health care costs for a large group of diseases. Springmann et al. (2016) and Springmann et al. (2020) provide estimation of these costs for countries based on their income levels. Though we use COI as the measure for health burden, it is worth to review another measure that is widely used in medical and food sciences.

Before presenting the calculation steps, it is worth reviewing a widely used measure of health impact and explain why it is not suitable for our purpose. Disability-adjusted life years (DALYs) is a measure that is widely used in medical sciences and also by WHO. This measure consists of two sub-measures. Years of life lost due to premature mortality (YLLs) and years of healthy life lost due to disability (YLDs). One DALY is equivalent to the loss of one year of full health. The advantage of using DALY as the measure for health burden of food consumption is that it is a well-known and widespread concept and, consequently, most researchers and practitioners understand it. Another advantage is that it is widely used and there are lots of independent studies that report it as the unit of measurement. For our purpose, however, DALY is not a good measure because it measures the number of years that are lost and this is mostly a personal loss, i.e., borne by the consumer and not the society. Another downside is that converting DALYs to a monetary value is often complicated and there is no standard method to monetise one DALY. The issue of not being

an externality makes DALY an uninteresting candidate for the purpose of true pricing of diet-related consumer health effects despite being very valuable for other purposes.

We are now ready to present the final steps.

Step 1: For the selected food or the ingredient, identify the diseases from the GBD that are correlated with it. That is, the diseases with non-zero risk factor attribution.

Step 2: Obtain the average cost of illness per patient from for the diseases that are identified in Step 1. In the Netherlands, use RIVM.¹⁴ Springmann (2020) provides estimates of healthcare costs for a limited number of diseases based on the income level of countries. Note that sometimes the average costs are not given directly but the total costs is presented. If this is the case, then we have to calculate the average cost by dividing the total costs by the number of patients in that year. Denote the average cost by \bar{C} .

Step 3: For each disease identified in Step 1, multiply the average cost of disease from step 2 with the footprint indicator from Section 5.3. That is, use the following formula to estimate the externality of the product of the interest.

$$FPI \times \bar{C} \quad (A)$$

Note that in the calculation of footprint indicator in Section 5.3, the marginal relative risk MRR depends on LC which itself depends on the defined duration of overconsumption. The longer the duration, the higher LC, lower MRR and FPI and lower the externality. We suggest calculating LC for two values. One with LC=5 and the other with LC=20. The first number provides an upper bound whereas the second one provides a lower bound on the externality. The difference between the lower and upper bounds can be considered as a measure of sensitivity of the estimations to the selection of time periods. The larger the difference, the more sensitive the estimations. Put another way, the closer the lower and upper bounds, the more robust the results are. In case the lower and upper bounds are considerably different, then these estimations should be considered more carefully and possibly be cross checked with other independent studies.

Step 4: Repeat steps 2 and 3 for all the diseases identified in Step 1. Add the costs for all the diseases. It gives the total external costs of consuming the product or the ingredient.

Finally, recall that FPI is unitless and the unit of \bar{C} is euro per person. So, the product of (A) has the same unit as \bar{C} . We can think of (A) as representing the reduction in the healthcare costs of a patient, in the counterfactual scenario of consuming one less unit of the food product.

7. Implementation: red meat and processed meat

The environmental and health impacts of production and consumption of red meat and processed meat have been the subject of much public and scientific debate. The environmental impacts are explored thoroughly, see Capper (2009) and Djekic (2015). The reservations on the health impacts of red and processed meat consumption led the International Agency for Research on Cancer (IARC) to study more than 800 studies regarding the association between red and processed meat consumption and cancer in various countries. As a result of this study, IARC has classified processed meat ‘carcinogenic to humans’

¹⁴ www.vzinfo.nl/kosten-van-zieken

and red meat 'probably carcinogenic to humans'.¹⁵ It shows that red meat and processed meat have considerable health effects. We implemented the procedure laid out in Sections 4 to 6 for the case of red meat and processed meat in the Netherlands.

Red meat refers to mammalian muscle meat that is not processed. It includes beef, veal, pork, mutton, lamb, horse meat and goat meat. The consumption includes consuming minced or frozen red meat. Red meat is a rich source of proteins and contains valuable micronutrients such as iron, zinc and vitamin B. Red meat is often consumed cooked or semi-cooked. Cooking improves the digestibility of red meat, but results in formation of particles that are suspected to be carcinogenic such as heterocyclic aromatic amines (HAA). Formation of suspicious particles happens most with high temperature cooking methods such as grilling and barbequing.

Processed meat refers to the meat that has been transformed in order to improve its flavour or enhance the preservation. The transformation takes the form of curing, salting, smoking and fermentation, among other. Processed meat often includes pork and beef, but other types of red meat and poultry and offal can also be processed. Processing methods such as curing and smoking results in the formation of carcinogenic chemical like polycyclic aromatic hydrocarbons (PAH) and N-nitroso compounds (NOC).

Finally, two points should be mentioned before proceeding to the calculations. First, note that meat consumption is also related to viruses, zoonoses, antibiotic resistance and salmonella contaminations. We, however, do not study these health effects because they depend on the food preparation methods and also because the safety aspect is out of scope of this module. Second, this report only estimates the externalities of the consumption side, i.e., the production side costs are not included. Meat production entails creating externalities as well. This happens in the form of emissions, water and air pollution, soil degradation and various types of environmental damages. As a result, the total value of the externalities, in the consumption and production sides, will be higher.

Finally, it should be mentioned that meat consumption is also related to viruses, zoonoses, antibiotic resistance and salmonella contaminations. We, however, do not study these health effects in this report.

7.1. Contribution factors

Recall, from Section 5.1, that we first need to derive the contribution factor of the food under consideration, red meat and processed meat. Note that the aim of calculating the contribution factor is to have a measure that shows how the consumption of a food product contributes to the consumption of the ingredient under consideration. We now implement this for the case of red meat and processed meat.

In the case of red meat, the product and the ingredient of interest are the same, red meat. Red meat is sold and consumed as a final food product. So, buying a kilo of red meat at a retail shop implies consumption of, almost, a kilo of red meat. Red meat is produced and sold in different forms that are different in terms of fat content. We do not incorporate fat content in our analysis since the available data sources do not allow us to do so. However, it is important to remember that the fat content, especially saturated fat, might have health implications that interact with the implications of the red meat itself. Given this introduction, we set the contribution factor equal to one, i.e., $C_r = 1$.

For the processed meat, the same arguments as for the case of red meat result in setting the contribution factor equal to one. It is worth to note that a remarkable difference between processed meat and red meat is their sodium content. Fresh red meat does not have a high amount of sodium whereas processed meat

¹⁵ https://www.iarc.who.int/wp-content/uploads/2018/07/pr240_E.pdf

is usually high in sodium. Diets high in sodium have been shown to be associated with negative health outcomes, Farquhar et al. (2015). As a result, part of the health impacts associated with processed meat might be attributable to the sodium content. Current studies, however, do not disentangle the effect of sodium from the processed meat and so we are not able to isolate the impact of sodium from processed meat itself.

Setting the contribution factor to 1 for both the red meat and processed meat warrants a caveat. As mentioned above, red meat and processed meat are produced in many types (pork, beef, etc.) and consumed in different ways (semi-cooked, barbeque, etc). Consumers in a specific country might have a preference for one type over another type. For example, in many Muslim countries pork is not consumed by the majority of consumers. The formulation in Section 5.1, the parameter p , implies that the contribution factor should take this point into account. That is, different types of red meat or processed meat should have different contribution factor depending on the consumption. This, however, requires detailed consumption data regarding meat consumption. At the moment, we do not have such detailed data, especially for processed meat. As a result, we consider all types of red meat, and processed meat, to be one type and set $p=1$.

7.2. Footprint indicators

To obtain the footprint indicators, we need to first identify the diseases associated with diets that are high in red meat and processed meat. Then, we proceed with the calculation of MRR and FRI according to the procedures in Sections 5.2 and 5.3.

Recall that MRR is calculated by

$$\text{MRR} = \exp\left(\frac{\text{Ln}(\text{RR})}{\text{LC}}\right)$$

Where RR is the relative risk taken from the Lancet Global Burden of Disease. LC requires defining and measuring consumption or overconsumption during an extended period of time. We estimate overconsumption in periods of 5 and 20 years. These numbers result from the fact that the data sources that report associations between consumption and health, monitor consumption over a long period of time and so we need to assume a minimum and a maximum time for the overconsumption to have health effects.

Red meat. According to the survey done by Dagevos and Verbeke (2022), the average consumption of meat is around 80kg, based on carcass weight. Of this amount poultry accounts for 20kg. Therefore, we can assume that the average consumption of red meat is around 60kg per year. Converting the carcass weight to consumption weight implies an amount of 30kg per capita per year. The Global Burden of Disease defines consuming more than 4 ounces (113 grams) of red meat per week as overconsumption. This amount to, roughly, 6 kg per year. As a result, the overconsumption of red meat per year is estimated to be 23kg. The corresponding numbers for 5 and 20 years are given by $\text{LC}(5)=115\text{kg}$ and $\text{LC}(20)=460\text{kg}$, respectively.

Processed meat. Data regarding processed meat consumption is less reliable compared to red meat. The estimations made by Wageningen Economic Research indicates per capita consumption around 20kg per year based on carcass weight. Unlike red meat, here we take the carcass weight as the consumption weight for two reasons. First, these estimations consider only household consumption and not outdoor consumption in restaurants and food companies and processed meat is the main type of meat consumed outdoor. Second, processed meat losses less weight, compared to red meat, when it is prepared for consumption. The Lancet Global Burden of Disease defines the recommended consumptions level of processed meat to be zero. So, all consumption is overconsumption and we have $\text{LC}(5)=100\text{kg}$ and $\text{LC}(20)=400\text{kg}$.

Next, we identify the diseases that are associated with overconsumption of red meat and processed meat, from the GBD, and extract the relative risks for the Netherlands. Finally, we apply the procedure outlined in Section 5.3 to calculate the associated footprints for red meat and processed meat.

Red meat. Table 7.1 shows the diseases that are associated with diets high in red meat together with the relative risks (RR) and marginal relative risks (MRR) for when LC =5 and LC=20. We state footprint indicators for the case of LC=5 and LC=20 and denote them by FPI (5) and FPI (20), respectively.

Table 7.1 Footprint and risk measures of red meat

Disease----- Indicators	RR	MRR(5)	FPI (5)	MRR(20)	FPI (20)
Ischemic heart diseases	1.083	1.0007	44×10^{-5}	1.0001	11×10^{-5}
Colorectal cancer	1.076	1.0006	5×10^{-4}	1.0001	12×10^{-5}
Diabetes	1.11	1.0009	7×10^{-4}	1.0002	18×10^{-5}
Stroke	1.12	1.0009	65×10^{-5}	1.0001	16×10^{-5}
Breast cancer	1.056	1.0004	36×10^{-5}	1.0001	1×10^{-5}

Processed meat. Table 7.2 replicates the same procedure for processed meat.

Table 7.2 Footprint and risk measures of processed meat

Disease----- Indicators	RR	MRR(5)	FTI (5)	MRR (20)	FTI (20)
Ischemic heart diseases	1.05	1.0006	65×10^{-5}	1.0001	16×10^{-5}
Colorectal cancer	1.06	1.0007	77×10^{-5}	1.00019	16×10^{-5}
Diabetes	1.13	1.0015	15×10^{-4}	1.00038	37×10^{-5}

7.3. Cost of illness

We estimate the average cost per capita for the diseases identified in Table 7.3. This is done by dividing the total healthcare cost for each disease, provided by RIVM at www.vzinfo.nl, by the total number of people diagnosed with that disease. We would like to warn the readers that these estimates must be taken with care. First of all, the number of people with a specific disease is not always reported by RIVM and so is not necessarily known accurately. Various institutions report these numbers based on the registration by family doctors and hospitals. Second and more important, not all those who are diagnosed with a disease receive healthcare service. Third, RIVM does not provide healthcare costs for stroke but has a category for heart failure (hartfalen). We think this category incorporates stroke as well but may give an overestimation for the real costs of stroke. Given these considerations, we try our best to make estimation based on available data. It is reported in Table 7.3.

Table 7.3 Cost of diseases 2019

Disease	Total Cost (€)	Number of Patients	Ave Cost per Patient (€/patient)
Colorectal cancer	558,000,000	82,000	6,804
Ischemic heart disease	1,400,000,000	774,000	1,808
Diabetes	1,300,000,000	110,0000	1,181
Breast Cancer	813,000,000	130,000	6,253
Stroke	538,000,000	120,000	4,483

Finally, using the risk factor attribution (RFA) from the GBD and the information of Table 7.3, we can estimate the average incidence of the diseases that can be attributed to the overconsumption of red meat and processed meat. Table 7.4 presents this data.

Table 7.4 Incidence of diseases attributable to the overconsumption of red and proceed meat

Disease	RFA (Red meat)	incidence attributed to overconsumption of red meat	RFA (processed meat)	incidence attributed to overconsumption of processed meat
Ischemic heart diseases	0.0674	5,529	0.049	4,018
Colorectal cancer	0.0767	59,366	0.0562	43,499
Diabetes	0.11	121,000	0.12	132,000
Stroke	0.105	13,650	0	0
Breast cancer	0.0537	6,444	0	0

7.4. Monetisation

We are now ready to estimate the marginal healthcare cost of consuming a kilo of red meat and processed meat. As we mentioned, for both the red meat and processed meat the contribution factor is 1. Therefore, the cost equals the product of the footprint factor and the average cost. Since there are two footprint indicators, one for the case when the long term consumption is calculated for 5 (upper bound) years and the other for the case when long-term consumption is calculated for 20 years (lower bound), we will have two estimates for each disease. The cost calculated by using 5 years consumption can be regarded as an upper bound and the one calculated by 20 years as a lower bound. The upper bound and the lower bound reflect the fact that the observed effect is driven by the overconsumption of red meat and processed meat in the long run. That is, the data is obtained by monitoring the consumption and health status of consumers over many years. However, the data does not exactly show how many years of overconsumption resulted in the observed health effect. Therefore, we need to take a minimum and maximum time as periods over which overconsumption affect health outcomes. Obviously, the higher the difference between the minimum and maximum, the higher the difference between the upper bound and lower bound will be. Table 7.5 and Table 7.6 shows the costs for red meat and processed meat, respectively.

Table 7.5 Healthcare cost associated with consuming a kilo of red meat

Disease	Upper Bound Cost per Kilo of Consumption (€)	Lower Bound Cost per Kilo of Consumption (€)
Colorectal cancer	4.3	1.08
Ischemic heart disease	1.0176	0.25
Diabetes	1.178	0.26
Breast cancer	1.78	0.71
Stroke	1.78	0.97
Total	10.86	3.3

As we see, colorectal cancer is the most costly disease associated with red meat consumption followed by stroke and breast cancer. The average cost associated with consuming a kilo of red meat can be estimated to be around 7.5 euros.

Table 7.6 Healthcare cost associated with consuming a kilo of processed meat

Disease	Upper Bound Cost per Kilo of Consumption (€)	Lower Bound Cost per Kilo of Consumption (€)
Colorectal cancer	3.96	1.0
Ischemic heart disease	1.17	0.22
Diabetes	1.78	0.37
Total	6.92	1.59

For processed meat, colorectal cancer is the most costly associated disease. The average cost associated with consuming a kilo of processed meat is estimated to be around 4.3 euro.

A notable difference between red meat and processed meat is that breast cancer and stroke are associated with the overconsumption of red meat but not processed meat. It might be the case that the overconsumption of red meat and processed meat often happens together. That is, those who overconsume red meat also overconsume processed meat. Another plausible cause could be the strict definition of recommended consumption level of processed meat, no consumption, by the GBD. Whatever the cause is, we recommend the readers to replicate the estimations with other data sources and compare the results with other estimations.

Recall that we presented the average incidence of diseases attributable to red and processed meat consumption and the average cost per patient per disease in Tables 7.3 and 7.4, respectively. Therefore, we can estimate the annual health costs attributable to the overconsumption of red meat and processed meat. This is done for the year 2019 in Table 7.7.

Table 7.7 Total health care costs in 2019

Disease	Average costs per (€/patient)	incidence (red meat), €/p	Total cost - red meat €	incidence (processed meat), €/p	Total cost - processed meat €
Ischemic heart diseases	1,808	5,529	10,000,000	4,018	7,264,544
Colorectal cancer	6,804	59,366	403,926,264	43,499	295,967,196
Diabetes	1,181	121,000	142,901,000	132,000	155,892,000
Stroke	4,483	13,650	61,192,950	0	0
Breast cancer	6253	6444	40,294,332	0	0
Total			658,314,546		459,123,740

As we can see, the total health care costs attributed to the overconsumption of red meat and processed meat exceeds one billion euros in 2019. Note that this number reflects the total effect of overconsumption over many years and so, it is quite different than the cost associated with the overconsumption of one kilo of red meat and processed meat.

8. Limitations and items for further development

Calculation of the health impact of food consumption is a complex task due to methodological issues and data availability limitations. Some of the most important issues are discussed below.

8.1. Limitations

As specified in earlier sections of this module, consumption of an unhealthy diet has a lot of effects. For example, the negative wellbeing effects on the consumer from a diet-related decrease in health are considered an externality in this method. Whether these effects are externalities in every context can be contested (see Section 3.2.3) and the decision to exclude them from the true price is therefore arbitrary.

This module does not include food safety costs and productivity loss resulting from food consumption due to the considerations outlined in Section 3. However, it should be noted that these costs might be considerable and have to be considered when estimating the total externalities of consumption of food products.

Food consumption is endogenous. It is part of the life style of people and is correlated with many other variables that also affect human health. In other words, there are many confounders. As a result, establishing a causal relationship between food consumption and health consequences without considering the effect of confounders results in biased estimations. Most studies in medical and food sciences follow econometric strategies that make them prone to the problems resulting from endogeneity.

The effect of food consumption on health status depends on the consumption level. The diet of the average consumers might not be a good representative for the major part of the society. This is more pronounced in societies where there are heterogenous dietary habits. The average diet might be balanced, but the majority of consumers' diets have very high or very low amount of a food.

No standard method exists to estimate the contribution of food products to the consumption of foods in a diet. The suggested formula of Section 5.1 is a first attempt in this direction. It requires further research and modification.

One specific consideration is the interrelation between some types of diseases. That is, one type of disease might cause, or increase the chance of contraction of, another disease. This makes the analysis difficult as these interrelated diseases usually appear together and so, the researchers have a hard time disentangling the effect of the main independent variable, food consumption, from the contribution of other diseases. There are statistical methods that can mitigate these interrelation effect and help isolating the effect of the variable of the interests. Credible research reports, such as the GBD, are aware of the issue and try to correct for it in their publications.

The effect of food consumption on diseases is not uniform across the consumers. Consumers are different in terms of their life style, genetic inclination, etc. Using averages might be misleading and can give inaccurate estimates.

Associational measures like risk ratio and odd ratio are interpreted as causal measures. Association might not imply causation. This is important especially in the health domain because there are many factors that affect the health status of individuals where many of them are either non-known completely or cannot be measured adequately.

Monetisation procedure depends critically on data availability. For specific diseases in specific countries, the cost of illness estimations might not be available.

8.2. Items for further research

We recommend the following activities as possible avenues for further research.

- Conducting research using quasi-experimental methods to evaluate the causal effects of food consumption on human health. This can be done by utilising existing data combined with a causal identification strategy. Conducting experimental studies might not be feasible due to legal, ethical and institutional concerns.
- Replicating the estimations using other monetisation methods, such as DALY, and comparing them to the estimations based on the methods introduced in this module. In case there is a considerable inconsistency between the estimations with different methods, then further investigation will be needed.
- Testing and further developing the contribution factor introduced in Section 5.1. Translating food consumption from the diet level to the product level is necessary for the monetisation procedure, but there are currently no standard method for doing so.

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