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# Valuation of the health and climate-change benefits of healthy diets

## Background paper for *The State of Food Security and Nutrition in the World 2020*

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# Valuation of the health and climate-change benefits of healthy diets

**Background paper for**
***The State of Food Security and Nutrition in the World 2020***

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## Abstract

Current diets are neither healthy, nor sustainable. The health and environmental consequences of our dietary choices impose costs on society that are currently not reflected in the price of those foods or diets that contribute to these detrimental impacts. Here we provide updated estimates of two major cost items: the healthcare-related costs associated with unhealthy diets, and the climate-change costs associated with the emissions attributable to diets and food production. We estimated those costs for current and projected diets, and for a set of healthier and more sustainable dietary patterns, including flexitarian, pescatarian, vegetarian and vegan diets. For 2030, we projected the health and climate-change costs of diets to amount to USD 1.3 and 1.7 trillion, respectively, and to increase by 68 percent and 234 percent by 2050. Compared to market costs, the health and climate-change costs had a value of 50 percent of the average wholesale costs of diets in 2030, reaching 97 percent in 2050. Adoption of healthier and more sustainable dietary patterns reduced the health costs by 92–97 percent, and the climate-change costs by 40–76 percent, with greatest reduction for the most plant-based diets. When the health and climate-change costs were included in the cost of diets, the healthier and more sustainable dietary patterns had lower wholesale costs, on average, than current and projected diets. Across regions, the relative cost reductions in 2030 ranged from up to 53 percent in high-income countries to up to 4 percent in low-income countries. Our results suggest that the health and climate-change costs of current diets are substantial and projected to increase. Adoption of healthier and more sustainable diets can significantly reduce these external costs. A fuller cost accounting increases the costs of current and projected diets, but also makes healthier and more sustainable dietary patterns more affordable in comparison.



**Keywords:** sustainable diets, healthy diets, food systems, cost of diet, food affordability, food security

**JEL codes:** Q11, Q52, Q54, Q56

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# 1 Introduction

Our diets are neither healthy, nor sustainable. Imbalanced diets, such as diets low in fruits and vegetables, high in red and processed meat, and excessive energy intake, represent one of the greatest health burdens globally and in most regions (GBD 2017 Diet Collaborators, 2019; GBD 2017 Risk Factor Collaborators, 2018), and the chronic diseases related to unhealthy diets – cardiovascular diseases, cancer and type-2 diabetes mellitus – require costly treatment (Muka *et al.*, 2015). The food system is also a major driver of environmental impacts (Poore and Nemecek, 2018) and without dietary changes towards more plant-based diets, key environmental limits related to climate change, land use, freshwater extraction, and biogeochemical flows associated with fertilizer application risk being exceeded (Springmann *et al.*, 2018a; Willett *et al.*, 2019).

The health and environmental consequences of our dietary choices impose costs on society – increased medical costs and the costs of climate damages are two example – that are currently not reflected in the price of those foods or diets that contribute to these detrimental impacts. Economists call such instances – where private actions impose costs on society – negative externalities which lead to market failures and overconsumption and production of, in this case, unhealthy and unsustainable foods and diets (Pigou, 1932). According to economic theory, correcting such market failures involves integrating the previously unaccounted costs in the price of goods, so that consumers and producers can make their production and consumption decision based on the full costs.

Here we provide estimates of two major cost items: the health costs and the climate-change costs that are associated with our dietary choices but are not currently reflected in the cost of diets. The analysis provides an update to a previous analysis of ours (Springmann *et al.*, 2016). In particular, it increases the number of dietary risk factors covered in the health analysis and valuation, it uses more recent emissions data in the environmental analysis, and it updates the diet scenarios to a standardised set of healthy and sustainable dietary patters that are analysed as a means of reducing the negative health and climate-change costs imposed on society.

In addition to providing estimates of the total health and climate-change costs of food consumption, we also contextualise them by comparison to the cost of diets measured at current wholesale market prices. Estimates of the full health and climate-change costs of food consumption can provide information on the overall investment needs in food policies that incentivise dietary changes towards healthier and more sustainable diets, whereas expressing the previously unaccounted costs of dietary choices in terms the costs of foods or diets can help in devising concrete fiscal policies that more specifically target such externalities, e.g. by providing incentives through taxes or subsidies.

# 2 Methods

We relied on established methods to estimate the health and climate-change costs of the diets (Springmann *et al.*, 2016). For estimating the health costs, we combined updated estimates of the health burden of dietary risks with cost-of-illness estimates, and for estimating the climate-change costs, we combined food-consumption data with updated emissions footprints and estimates of the costs of climate damages associated with such emissions as expressed in the social cost of carbon. A description of the health and emissions estimates of diets, including a comprehensive description of the methods used is provided in a previous paper (Springmann *et al.*, 2018c). Here we focus on describing how we combined the various methods and estimates for the purpose of this study.

## 2.1 Baseline data

Underlying the analysis are estimates of current and future food consumption and alternative consumption scenarios that have been devised as being healthier and more sustainable. In line with our previous analyses, we adopted estimates of food demand for 157 countries and regions from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) (Robinson *et al.*, 2015), and we adjusted those estimates for food waste at the household level to obtain a proxy for food consumption. In the model, current food demand is based on a harmonised dataset of food-availability estimates of the Food and Agriculture Organization of the United Nations (FAO), and future demand is estimated by the model based on how expected changes in income, population, and dietary preferences affect food demand, similar to other estimates (Valin *et al.*, 2014). For our analysis, we focus on the health and climate-change burden in the year 2030 as a politically relevant time frame in light of the Sustainable Development Goals for 2030 (UN, 2015), and we provide analyses for the years 2010 and 2050 in a sensitivity analysis.

For analysing by how much the health and climate-change costs of diets can be reduced, we adopted a range of healthy and sustainable dietary patterns that were developed by the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems based on a comprehensive review of the literature on healthy eating (Willett *et al.*, 2019). The diets included flexitarian diets which contain small to moderate amounts of all animal-source foods, pescatarian diets which contain moderate amounts of fish but no other meat, vegetarian diets which contain moderate amounts of dairy and eggs, but no fish or other meat, and vegan diets which are completely plant-based. Previous analyses have evaluated the nutritional, health, and environmental benefits of adopting those diets (Springmann *et al.*, 2018a, 2018c; Willett *et al.*, 2019), but no economic valuation of their health and environmental impacts has been provided.

The more specialised dietary patterns were constructed by replacing the amount of animal products in the flexitarian diets. Because the exact composition of those diets is variable, we constructed two variants of each pattern, in which animal products were replaced by a mix of fish (pescatarian) or legumes (vegetarian, vegan) and either fruits and vegetables (high-veg variant) or whole grains (high-grain variant). The two variants of each specialised dietary pattern are meant to capture the diversity of such patterns and highlight particular trade-offs that are relevant for affordability as whole grains are usually cheaper per calorie than fruits and vegetables. The high-grain variants contain the same amount of fruits and vegetables as the flexitarian diets, and 2–9 percent more grains (by weight) than the high-veg variants (which still is about a third less than current diets). Table 1 provides an overview of the different dietary patterns considered in the analysis.

**Table 1. Overview of food consumption (g/day) in 2010 by diet scenarios (net of waste)**

| Food group | Diet scenarios | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BMK | FLX | PSCveg | PSCgrn | VEGveg | VEGgrn | VGNveg | VGNgrn |
| Wheat | 117 | 91 | 91 | 94 | 91 | 96 | 91 | 101 |
| Rice | 126 | 81 | 81 | 83 | 81 | 85 | 81 | 88 |
| Maize | 33 | 23 | 23 | 24 | 23 | 24 | 23 | 25 |
| Other grains | 22 | 15 | 15 | 15 | 15 | 15 | 15 | 16 |
| Roots | 134 | 101 | 101 | 101 | 101 | 101 | 101 | 101 |
| Legumes | 17 | 50 | 50 | 50 | 62 | 62 | 78 | 78 |
| Soybeans | 5 | 25 | 25 | 25 | 31 | 31 | 35 | 35 |
| Nuts and seeds | 13 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |
| Vegetables | 227 | 353 | 395 | 353 | 423 | 353 | 494 | 353 |
| Fruits (temp) | 37 | 62 | 69 | 62 | 73 | 62 | 87 | 62 |
| Fruits (trop) | 62 | 101 | 114 | 101 | 123 | 101 | 148 | 101 |
| Fruits (starch) | 28 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Sugar | 51 | 27 | 27 | 27 | 27 | 27 | 27 | 27 |
| Oil (palm) | 6 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Oil (veg) | 22 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |
| Beef | 25 | 5 | | | | | | |
| Lamb | 5 | 2 | | | | | | |
| Pork | 38 | 5 | | | | | | |
| Poultry | 31 | 19 | | | | | | |
| Eggs | 22 | 10 | 10 | 10 | 10 | 10 | | |
| Milk | 221 | 155 | 155 | 155 | 155 | 155 | | |
| Shellfish | 6 | 7 | 15 | 15 | | | | |
| Fish (freshwater) | 8 | 14 | 26 | 26 | | | | |
| Fish (pelagic) | 3 | 5 | 10 | 10 | | | | |
| Fish (demersal) | 5 | 7 | 15 | 15 | | | | |

Note: The diet scenarios include baseline/benchmark diets (BMK), flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants.

Source: Author's own elaboration.

## 2.2 Analysis of health costs

For estimating the health burden of diets, we followed methods developed by the Global Burden of Disease (GBD) project and used a comparative risk assessment framework of dietary and weight-related risks (Murray *et al.*, 2012). The assessment included four disease endpoints, including coronary heart disease, stroke, type-2 diabetes mellitus, cancer (in aggregate and as site-specific ones, such as colon and rectum cancer) (Springmann *et al.*, 2018c), in line with available cost-of-illness estimates (Springmann *et al.*, 2016). The risk factors included seven dietary risks, including low intake of fruits, vegetables, legumes, nuts, whole grains, and fish, as well as high intake of red meat, and processed meat, and three weight-related risks, including being underweight, overweight or obese. The relative risk estimates that relate the risk factors to the disease endpoints were adopted from meta-analyses of prospective cohort studies (Afshin *et al.*, 2014; Aune *et al.*, 2016a, 2016b, 2016c; Bechthold *et al.*, 2019; Chan *et al.*, 2011; Schwingshackl *et al.*, 2017; The Global BMI Mortality Collaboration, 2016; Zheng *et al.*, 2012).

Compared to earlier assessments (Springmann *et al.*, 2018c), we updated the data on weight distributions (NCD-RisC, 2016), and the relative risks related to weight levels (NCD-RisC, 2016), and red and processed meat (Bechthold *et al.*, 2019; Schwingshackl *et al.*, 2017). We used data from the Global Dietary Database to allocate total red meat consumption into unprocessed red meat and processed red meat, and to allocate total grain consumption into whole grains and processed grains (Micha *et al.*, 2015).

In a comparative risk assessment, the burden of diet-related diseases is typically calculated by comparison to a state of minimal risk exposure. For this analysis, we used as minimal risk exposure that dietary pattern out of the set of healthy and sustainable dietary patterns that was associated with the greatest health benefits.

For estimating the health costs of diets, we paired the estimates of cause-specific attributable deaths obtained from the comparative risk assessment with cost-of-illness estimates. The latter capture both the direct and indirect costs associated with treating a specific disease, including medical and healthcare costs (direct), and costs of informal care and from lost working days (indirect) (see e.g. ref (Leal *et al.*, 2006)). For our calculations, we used a global set of country-specific cost-of-illness estimates developed by Springmann and colleagues (Springmann *et al.*, 2016). The dataset is based on detailed cost-of-illness estimates for cardiovascular diseases (Leal *et al.*, 2006; Nichols *et al.*, 2012) and cancer (Luengo-Fernandez *et al.*, 2013) across the European Union (Leal *et al.*, 2006; Nichols *et al.*, 2012) (Luengo-Fernandez *et al.*, 2013) which were transferred to other regions by scaling the base values by the ratio of health expenditure per capita for direct costs, and by the ratio of gross domestic product (GDP) per capita (adjusted for purchasing power parity) for indirect costs. The dataset also includes country-specific cost estimates for diabetes (Zhang *et al.*, 2010) that were adjusted for co-morbidities to avoid double-counting of cardiovascular-disease-related complications (American Diabetes Association, 2013; Köster *et al.*, 2011). Table 2 provides an overview of the cost estimates.

**Table 2. Healthcare-related costs in 2030 (2010-USD per case of death) by region, cause of death and cost component**

| Region | Cause | Cost component | | | | |
|---|---|---|---|---|---|---|
| | | Total | Direct | Indirect | Indirect (labour) | Indirect (care) |
| **Global** | CHD | 101 013 | 34 529 | 66 871 | 29 071 | 37 799 |
| | Stroke | 80 748 | 36 591 | 44 326 | 18 740 | 25 586 |
| | Cancer | 141 459 | 64 256 | 77 686 | 53 707 | 23 980 |
| | T2DM | | 122 535 | | | |
| **High-income countries** | CHD | 249 503 | 119 741 | 129 762 | 56 413 | 73 349 |
| | Stroke | 227 019 | 141 611 | 85 408 | 36 109 | 49 299 |
| | Cancer | 291 576 | 162 954 | 128 622 | 88 921 | 39 703 |
| | T2DM | | 671 494 | | | |
| **Upper-middle-income countries** | CHD | 117 192 | 37 391 | 81 627 | 35 487 | 46 140 |
| | Stroke | 106 992 | 52 691 | 55 389 | 23 417 | 31 971 |
| | Cancer | 118 992 | 49 265 | 72 895 | 50 395 | 22 501 |
| | T2DM | | 104 099 | | | |
| **Lower-middle-income countries** | CHD | 67 064 | 14 956 | 52 166 | 22 679 | 29 487 |
| | Stroke | 64 939 | 23 423 | 41 530 | 17 558 | 23 972 |
| | Cancer | 85 668 | 24 143 | 61 560 | 42 558 | 19 002 |
| | T2DM | | 24 646 | | | |
| **Low-income countries** | CHD | 19 241 | 4 946 | 14 460 | 6 286 | 8 174 |
| | Stroke | 16 911 | 7 226 | 9 867 | 4 171 | 5 695 |
| | Cancer | 19 423 | 6 427 | 13 309 | 9 201 | 4 108 |
| | T2DM | | 4 821 | | | |

Note: The causes of death include coronary heart disease (CHD), stroke, cancer and type-2 diabetes mellitus (T2DM).

Source: Author’s own elaboration.

## 2.3 Analysis of climate-change costs

For estimating the climate-change costs of diets, we first calculated the GHG emissions associated with food consumption and then paired those with cost estimates of climate damages. For the former, we adopted a set of emissions factors derived from life-cycle assessments, including a global life cycle assessment with regional detail covering livestock products that was undertaken by FAO (Gerber *et al.*, 2013), and a comprehensive meta-analysis of life cycle assessments of other food products (Tilman and Clark, 2014). The assessments included all main emissions (carbon dioxide, methane, nitrous oxide) and sources along the food supply chain from the farm gate to the retail point, including production, processing, transport, including international trade, and, for livestock products, also land use and feed production. For fish and seafood, we differentiated between wild-caught and farmed fish production (Chan *et al.*, 2017; Rosegrant *et al.*, 2017) and the associated emissions footprints (Clune, Crossin and Verghese, 2017; Hall *et al.*, 2011).

For future years, we accounted for improvements in the emissions intensities of foods over time by incorporating the mitigation potential of bottom-up changes in management practices and technologies from marginal abatement cost curves (Beach *et al.*, 2015), in line with previous assessments (Springmann *et al.*, 2018a). The mitigation options included changes in irrigation, cropping and fertilization that reduce methane and nitrous oxide emissions for rice and other crops, as well as changes in manure management, feed conversion and feed additives that reduce enteric fermentation in livestock. In line with commitments made as part of the Sustainable Development Goals, we also include a halving of food loss and waste by 2030 in our development pathway. Table 3 provides an overview of the emissions footprints used in the analysis.

**Table 3. GHG emissions footprints in 2030 (kg$CO_2$-eq per kg of product) by food commodity and regions**

| Food commodity | Global | High-income countries | Upper-middle-income countries | Lower-middle-income countries | Low-income countries |
|---|---|---|---|---|---|
| **Wheat** | 0.37 | 0.37 | 0.39 | 0.37 | 0.37 |
| **Rice** | 1.55 | 1.49 | 1.44 | 1.63 | 1.51 |
| **Maize** | 0.36 | 0.36 | 0.38 | 0.36 | 0.36 |
| **Other grains** | 0.36 | 0.34 | 0.37 | 0.36 | 0.37 |
| **Roots** | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **Legumes** | 0.29 | 0.29 | 0.28 | 0.31 | 0.29 |
| **Soybeans** | 0.27 | 0.27 | 0.28 | 0.27 | 0.27 |
| **Nuts and seeds** | 0.54 | 0.57 | 0.53 | 0.53 | 0.51 |
| **Vegetables** | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| **Fruits (temperate)** | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| **Fruits (tropical)** | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **Fruits (starch)** | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| **Sugar** | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 |
| **Palm oil** | 4.92 | 4.92 | 4.93 | 4.92 | 4.92 |
| **Vegetable oil** | 2.06 | 1.65 | 1.74 | 2.16 | 2.75 |
| **Beef** | 36.82 | 16.18 | 43.61 | 38.69 | 41.85 |
| **Lamb** | 20.12 | 15.95 | 21.39 | 20.42 | 22.06 |
| **Pork** | 3.16 | 2.77 | 3.68 | 3.11 | 2.97 |
| **Poultry** | 2.16 | 1.89 | 2.26 | 2.24 | 2.01 |
| **Eggs** | 1.82 | 1.54 | 1.89 | 1.75 | 2.32 |
| **Milk** | 3.07 | 1.31 | 3.21 | 3.01 | 5.28 |
| **Shellfish** | 1.55 | 0.39 | 2.36 | 1.61 | 1.28 |
| **Fish (freshwater)** | 1.95 | 1.34 | 1.88 | 2.42 | 0.72 |
| **Fish (pelagic)** | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 |
| **Fish (demersal)** | 0.53 | 0.78 | 0.43 | 0.75 | 0.06 |

Source: Author's own elaboration.

For monetizing the GHG emissions, we used estimates of the social cost of carbon (SCC) which represents the economic cost caused by an additional ton of GHG emissions. Compared to our earlier study (Springmann *et al.*, 2016), we used estimates from a fully revised version of the Dynamic Integrated model of Climate and the Economy (DICE) for a scenario that constrains future temperature rise (with the temperature limit averaged over 100 y) in line with stated policy goals (Nordhaus, 2017). The SCC values in that scenario were USD/t$CO_2$-eq 107, 204 and 543 for the years 2015, 2030 and 2050. An alternative would have been to adopt SCC values obtained for different discount rates (that are used to convert future damages to present values) for a reference path with current policies, or to adopt SCC values for an "optimal control" path, but neither of these options fulfilled stated policy objectives with respect to limiting climate change.

### 2.4 Comparison to wholesale costs of diets

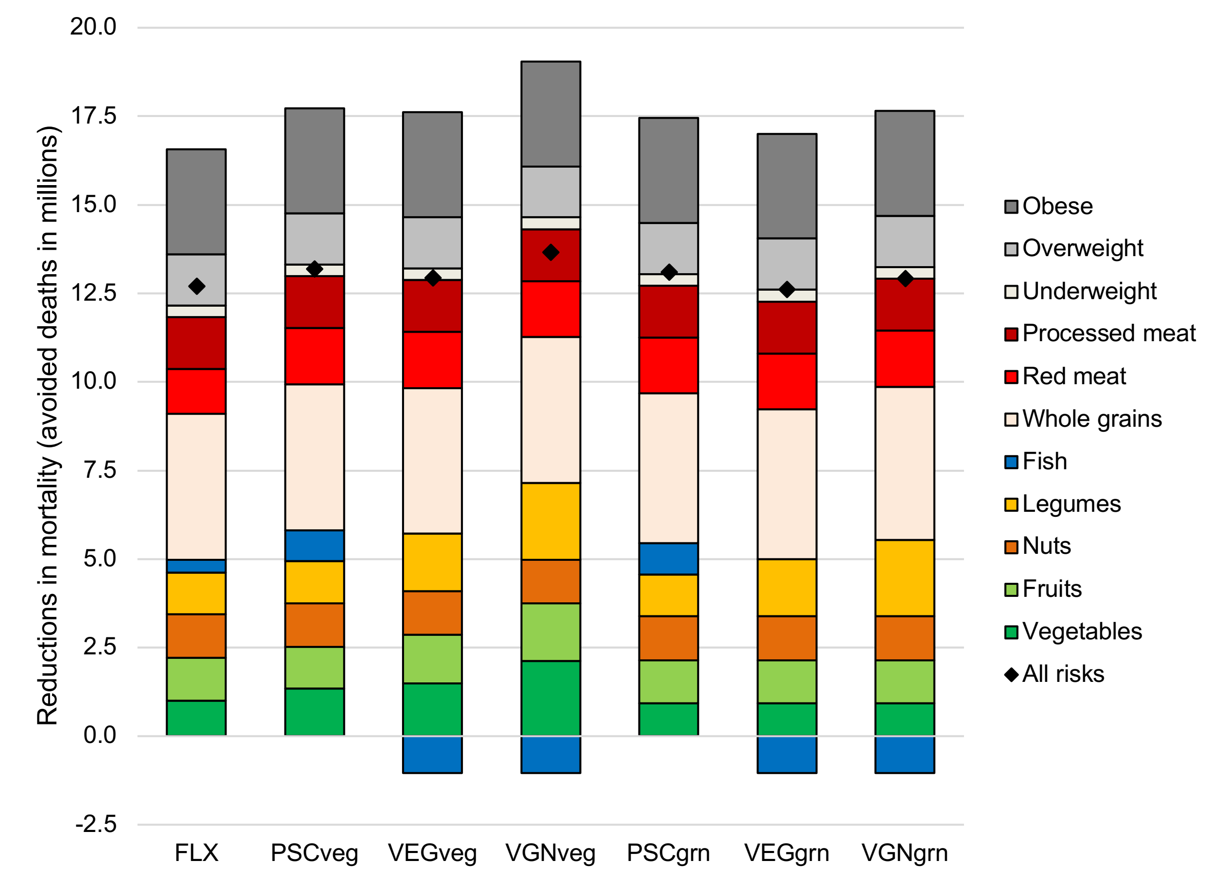
For contextualising the health and climate-change costs of diets, we compared those to the wholesale costs of diets based on estimates of commodity prices per region. We calculated diet costs by pairing estimates of food demand for the different consumption patterns with estimates of commodity prices. We adopted estimates of current and future commodity prices for 157 countries and regions from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) (Robinson *et al.*, 2015). In the model, regional commodity prices are endogenously determined by market-clearing conditions that take into account changes in world prices, trade policies and costs, and producer and consumer support measures in national markets. Commodity prices in the base year and estimates of consumer and producer support measures were based on data from the Agricultural Market Access Database of the Organisation for Economic Co-operation and Development (OECD, 2010, 2014), and estimates of export and import tariffs were adopted from the Global Trade Analysis Project (GTAP) (Boumellassa, Laborde and Mitaritonna, 2009; ITC, 2006; Narayanan and Walmsley, 2008). For our analysis, we adopted IMPACT's estimates of consumer prices for a middle-of-the-road socio-economic development trajectory (O'Neill *et al.*, 2015; Robinson *et al.*,2015).

# 3 Results

## 3.1 Health costs

Across the different healthy and sustainable dietary patterns, the greatest potential reduction in mortality was associated with adoption of high-veg vegan dietary patterns (Figure 1). Measured against this benchmark, baseline diets were associated with 13.7 (7.9–19.4) million avoidable deaths globally in 2030, representing 22.1 percent (12.8–31.4 percent) of all deaths (amongst adults). Across risk factors, about 70 percent of the avoidable deaths were due to imbalances in dietary composition, including too low consumption of whole grains (6.7 percent), fruits (2.7 percent), vegetables (3.4 percent), legumes (3.5 percent), nuts (2.0 percent), and too high consumption of red meat (2.6 percent) and processed meat (2.4 percent), whereas 30 percent was due to imbalanced weight levels, including underweight (0.5 percent), overweight (2.3 percent), and obesity (4.8 percent). Across causes of death, about half of the avoidable deaths (48 percent) were from coronary heart disease, a fifth each (21–23 percent) from stroke and cancer, and about a tenth (8 percent) due to type-2 diabetes mellitus.

**Figure 1. Reductions in mortality in terms of avoided deaths (in millions) by risk factor and dietary pattern in 2030**



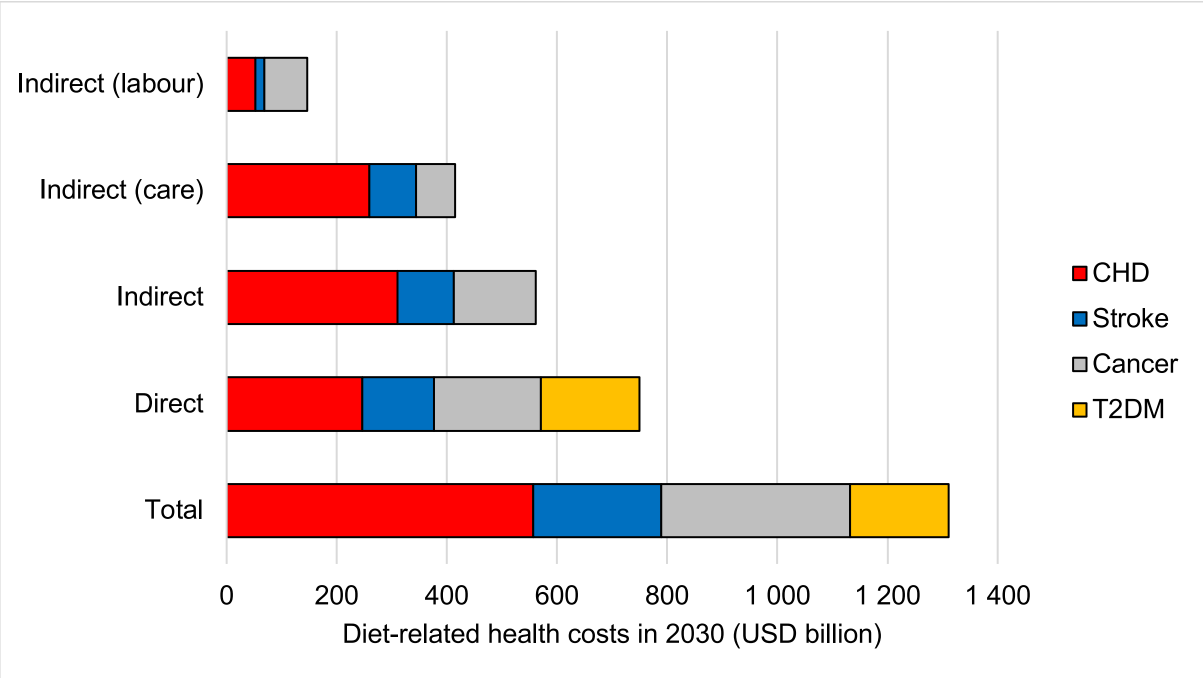

Note: The diet scenarios include flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants (see Table 1).

Source: Author's own elaboration.

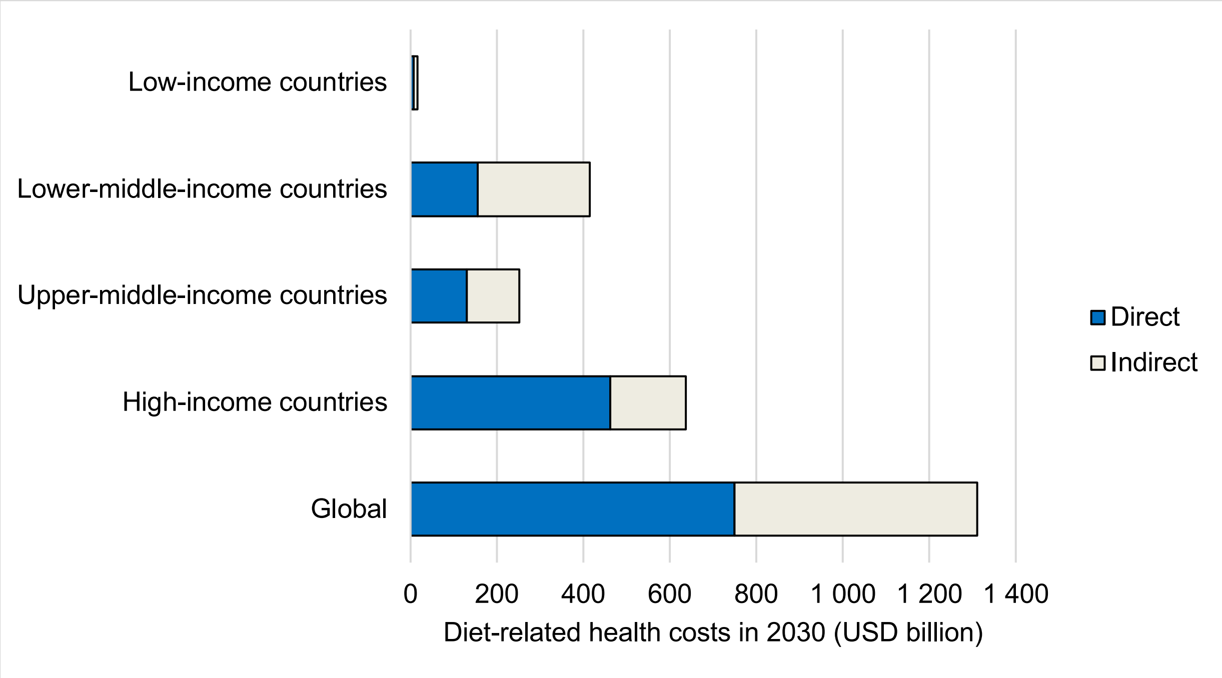
The avoidable healthcare-related costs of baseline diets amounted to USD 1.3 (USD 0.9–1.7) trillion in 2030, which represented 7 percent (5–9 percent) of the level of healthcare expenditure in that year (Figure 2a). More than half (57 percent) of the health costs were direct healthcare costs associated with expenses related to treating the different diet-related diseases, whereas the other part (43 percent) was due to indirect costs, including losses in labour productivity (11 percent) and informal care (32 percent). Across regions (Figure 2b), the level of avoidable costs was in line with the general level of healthcare spending and with the level of population, with greatest avoidable costs in high-income countries (USD 637 billion in total), followed by lower-middle-income countries (USD 415 billion), upper-middle-income countries (USD 252 billion), and low-income countries (USD 17 billion in total). Dietary changes towards healthier and more plant-based dietary pattern reduced healthcare-related costs by USD 1.2–1.3 trillion (Figure 2c).

**Figure 2. Diet-related health costs in 2030 (USD billion)**

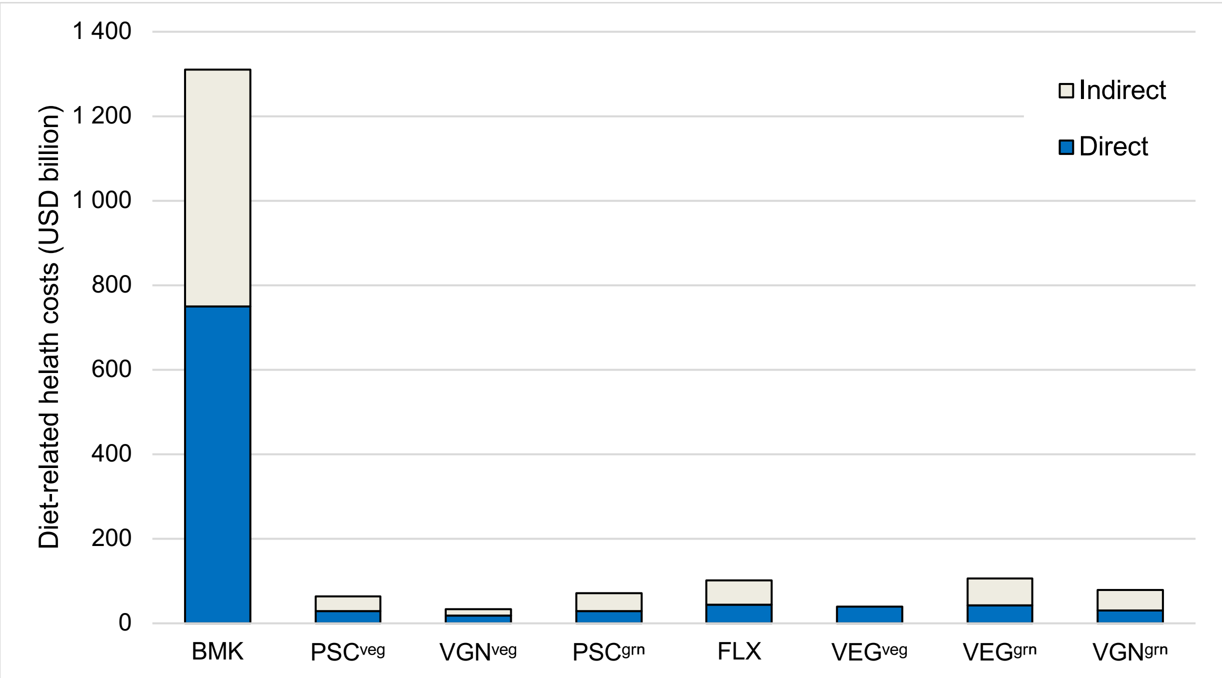
**a) By cost component and diet-related disease**



**b) By region and cost component**



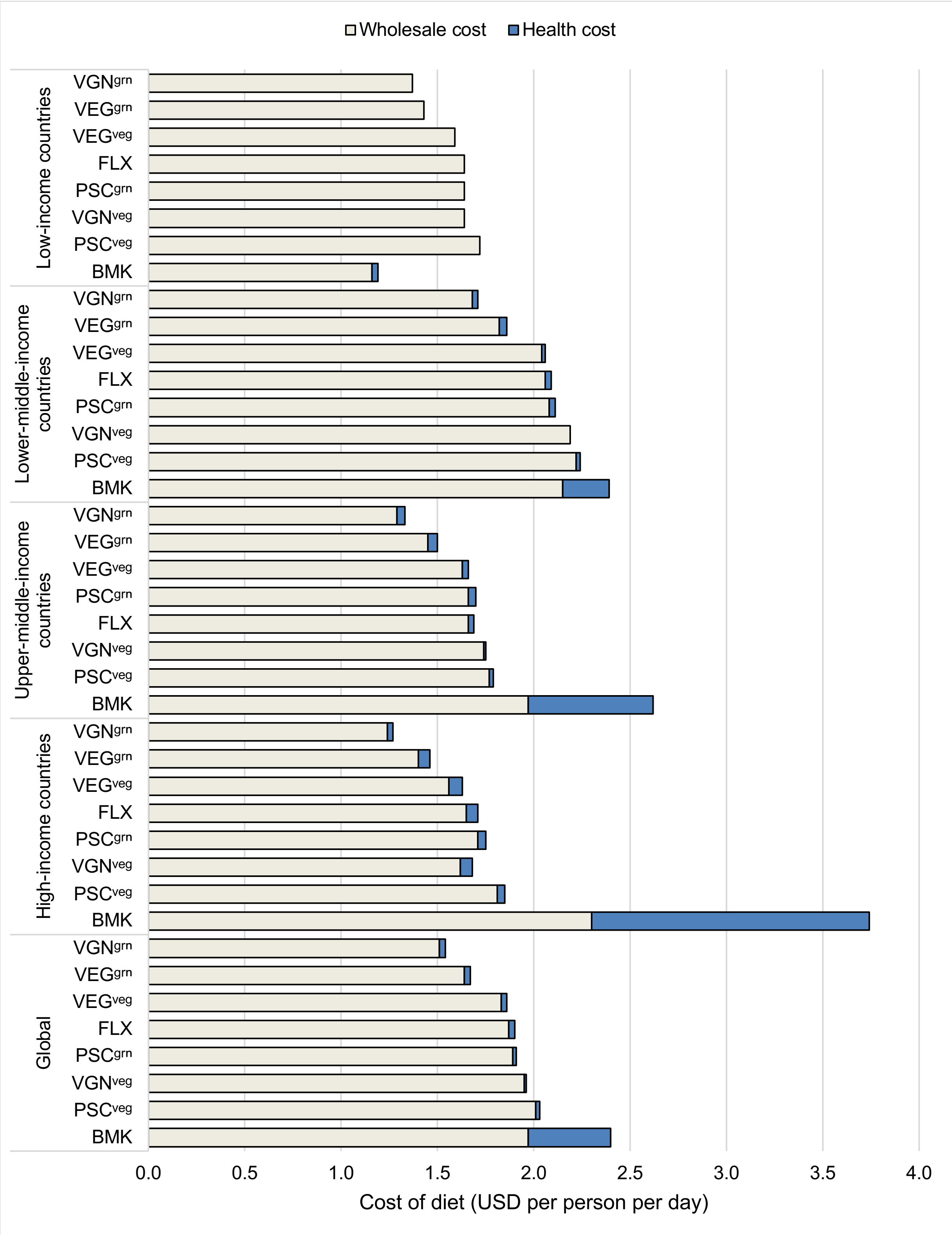

**c) By dietary pattern and cost component**




Note: The diseases include coronary heart disease (CHD), stroke, cancer and type-2 diabetes mellitus (T2DM). The diet scenarios include flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants (see Table 1).

Source: Author's own elaboration.

**Figure 3. Cost of diet (USD per person per day) in 2030 by region and dietary pattern in terms of wholesale costs and health costs**




Note: The diet scenarios include baseline/benchmark diets (BMK), flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants (see Table 1).

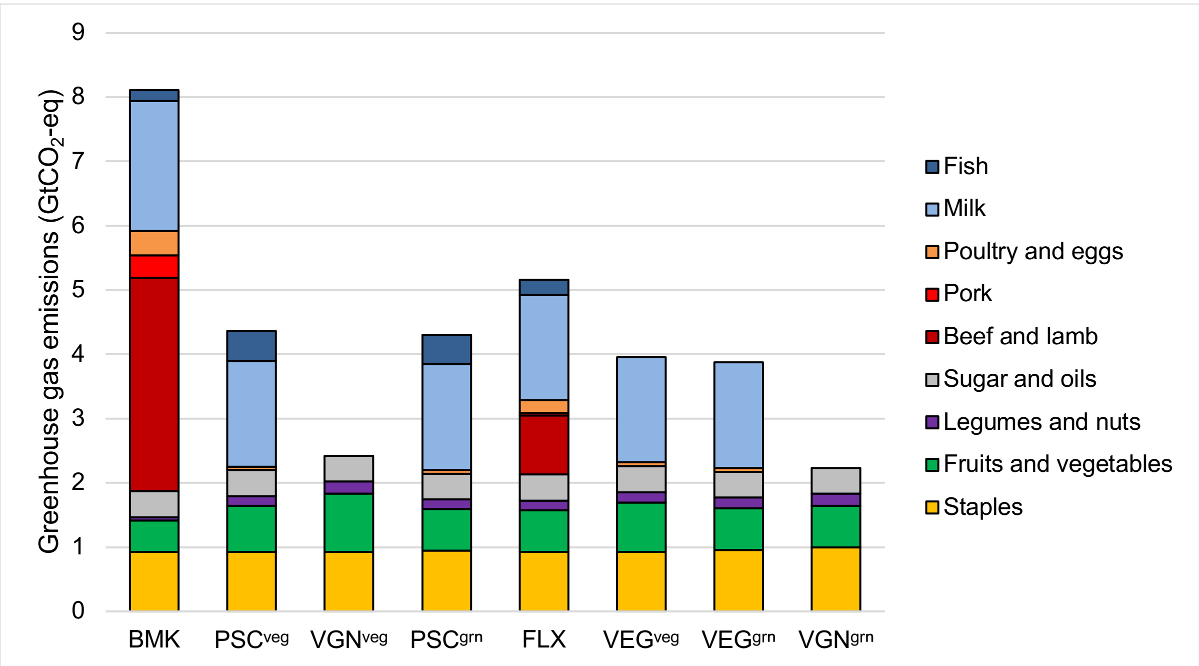
Source: Author's own elaboration.

If the healthcare-related costs of unhealthy diets were levied onto the cost of diets, then those would increase by 22 percent (USD 0.43 per person per day) on average, ranging from 3 percent (USD 0.03 per person per day) in low-income countries to 63 percent (USD 1.44 per person per day) in high-income countries (Figure 3). Under this health-cost accounting, healthier diets became relatively more affordable. Whereas the wholesale cost of the healthy benchmark diet was 1 percent less than baseline diets on average, the savings increased to 18 percent under health-cost accounting. Across regions, the savings ranged from 8 percent in lower-middle-income countries to 55 percent in high-income countries. In low-income countries, healthier diets remained more expensive, but the cost differential was reduced from 41 percent to 38 percent.

## 3.2 Climate-change costs

Diet-related GHG emissions amounted to 8.1 $GtCO_2$-eq in 2030, which represent 13 percent of estimated total GHG emissions in that year (Figure 4). More than three quarters (77 percent) of the diet-related GHG emissions were associated with animal-source foods, including beef and lamb (41 percent), and milk and dairy (25 percent) which were the greatest contributors. More than half of all emissions (52 percent) were associated with food demand from lower-middle-income countries, whereas per-capita emissions were largest in upper-middle-income countries (1.6 tCO2-eq) and lowest in low-income countries (0.7 tCO2-eq). Diet-related emissions of healthy and more plant-based dietary patters were up to three quarters (76 percent) lower than those of baseline diets.

**Figure 4. Food-related GHG emissions ($GtCO_2$-eq) in 2030 by food group and dietary pattern**

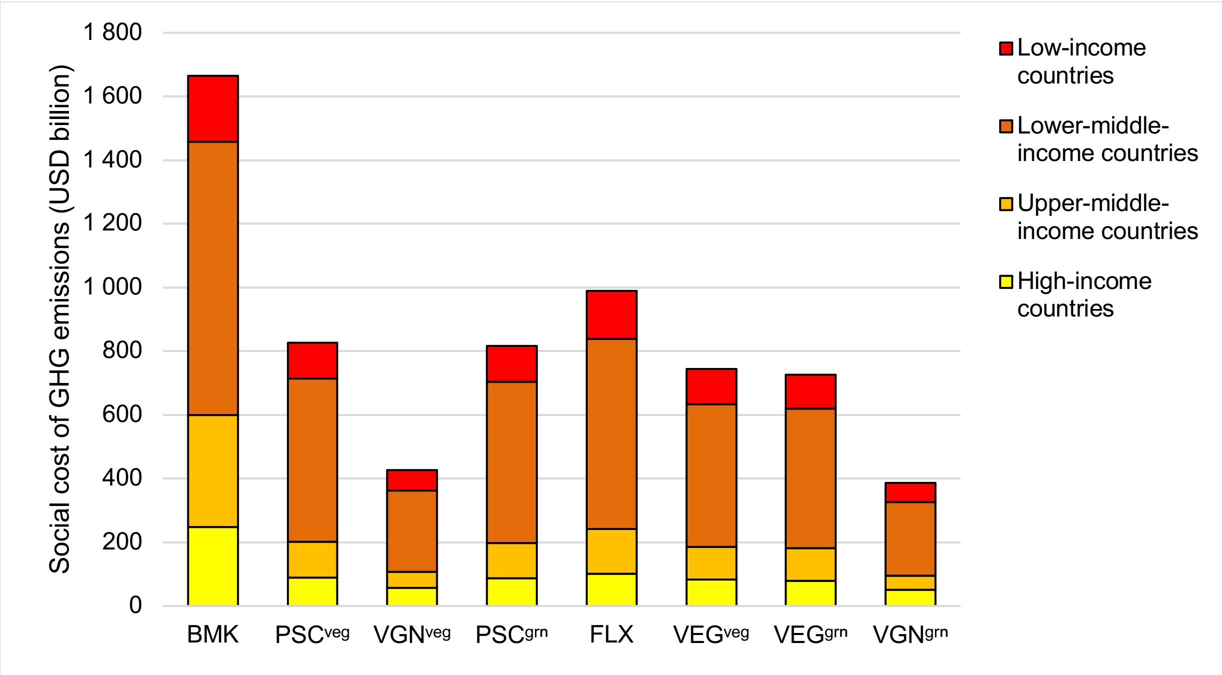



Note: The diet scenarios include baseline/benchmark diets (BMK), flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants (see Table 1).

Source: Author's own elaboration.

The social cost of GHG emissions (Figure 5) amounted to USD 1.7 trillion in 2030 for a climate-stabilization scenario. In line with the regional distribution of emissions, lower-middle-income countries accounted for half of the damage costs (52 percent), upper-middle-income countries for a fifth (21 percent), and high and low-income countries for 13–25 percent each. Adoption of more plant-based dietary patterns led to reductions of the social cost of GHG emissions of USD 0.8–1.3 trillion (50–76 percent), with greatest reductions for the most plant-based diets, in line with the achievable emissions reductions (Figure 4).

**Figure 5. Social cost of GHG emissions (USD billion) in 2030 by diet scenario and distribution across regional income groups**



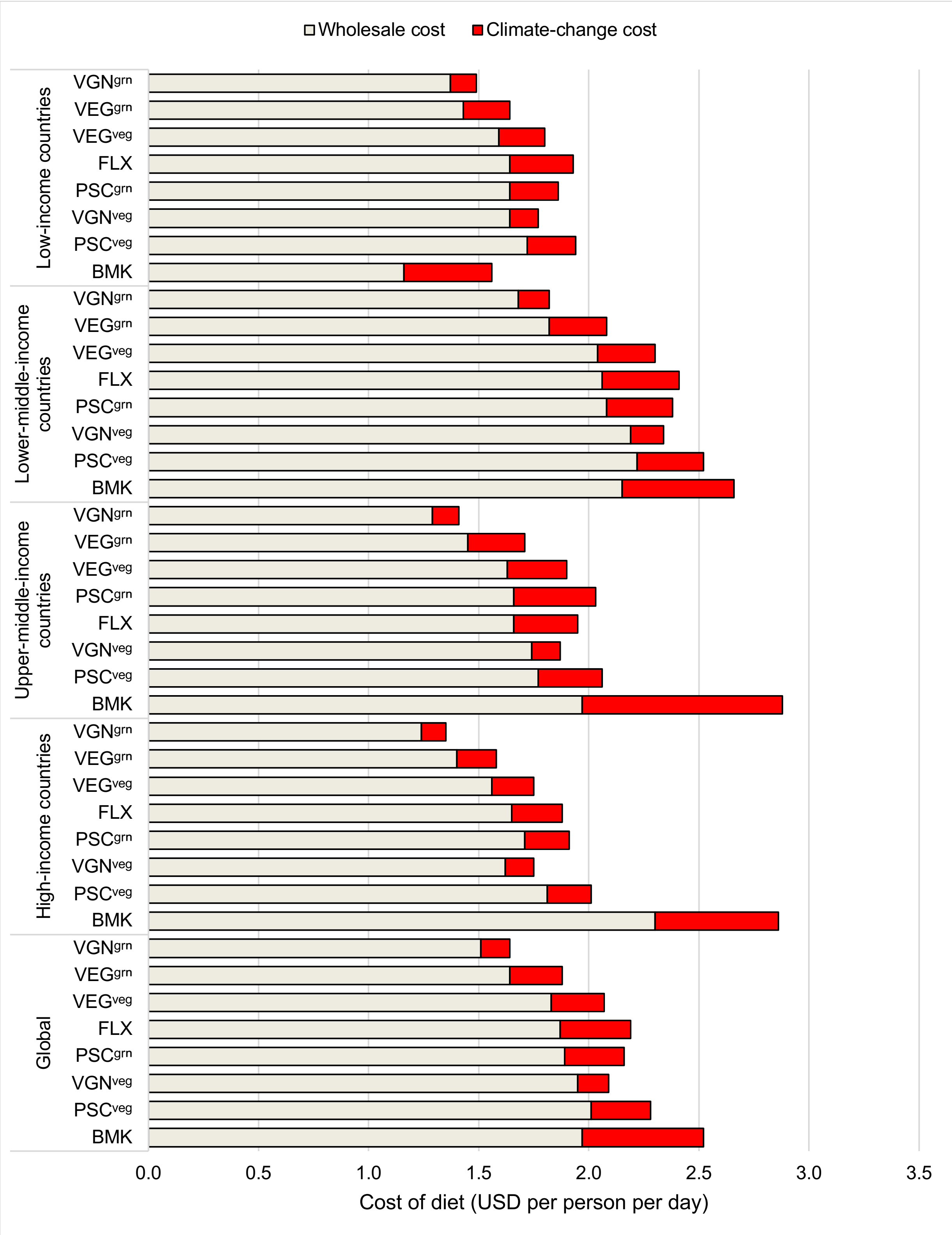

Note: The diet scenarios include baseline/benchmark diets (BMK), flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants (see Table 1).

Source: Author's own elaboration.

If the diet-related social costs of climate change were included in the cost of diets, then those would increase by 28 percent on average, ranging from 23 percent in lower-middle-income countries to 46 percent in upper-middle-income countries (Figure 6). Under climate-change accounting, the cost savings of healthier and more plant-based diets would increase from 1 percent to 17 percent on average, ranging from 12 percent in lower-middle-income countries to 39 percent in high-income countries. In low-income countries, the additional cost of healthier and more plant-based diets would decrease from 41 percent to 13 percent.

Combining the health and climate-change costs increased the cost of diets by 50 percent on average, ranging from 38 percent in low-income countries to 87 percent in high-income countries (Figure 8). The relative cost savings of the healthier and more plant-based diets amounted to 10–37 percent on average, ranging from up to 53 percent in high-income countries to up to 4 percent in low-income countries, with greatest savings for completely plant-based (vegan) diets.

**Figure 6. Cost of diet (USD per person per day) in 2030 by region and dietary pattern in terms of wholesale costs and climate-change costs**



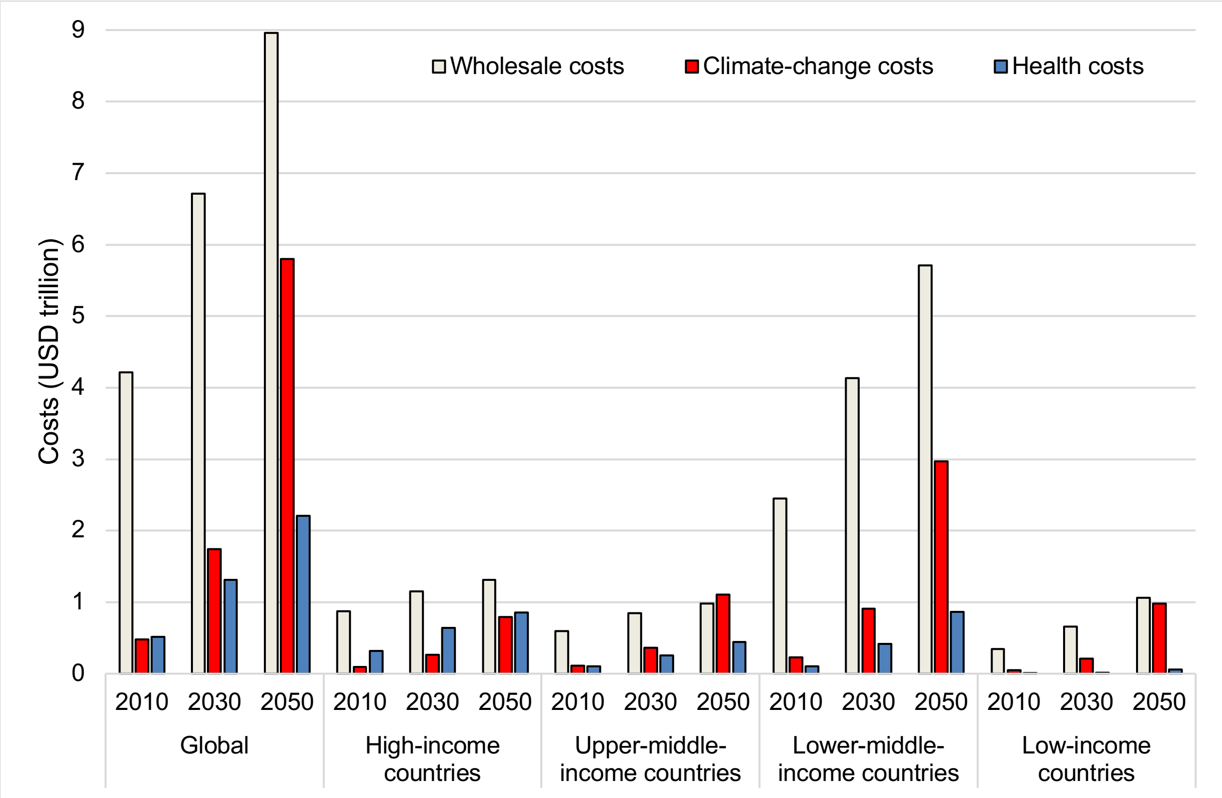

Note: The diet scenarios include baseline/benchmark diets (BMK), flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants (see Table 1).

Source: Author's own elaboration.

### Sensitivity analysis

The main analysis is focused on the year 2030, which is a policy-relevant time horizon and in line with the target year of the Sustainable Development Goals. In the sensitivity analysis (Figure 7), we analysed how the health and climate-change impacts of diets change for current years (based on data for the year 2010) and for future years (here we use 2050 as the target). In 2010, wholesale costs of diets were 37 percent lower due to lower commodity prices, health costs were 60 percent lower due to lower health expenditure and less unhealthy diets in low and middle-income countries, and the climate-change costs were 72 percent lower due to less food-related emissions from a smaller population.

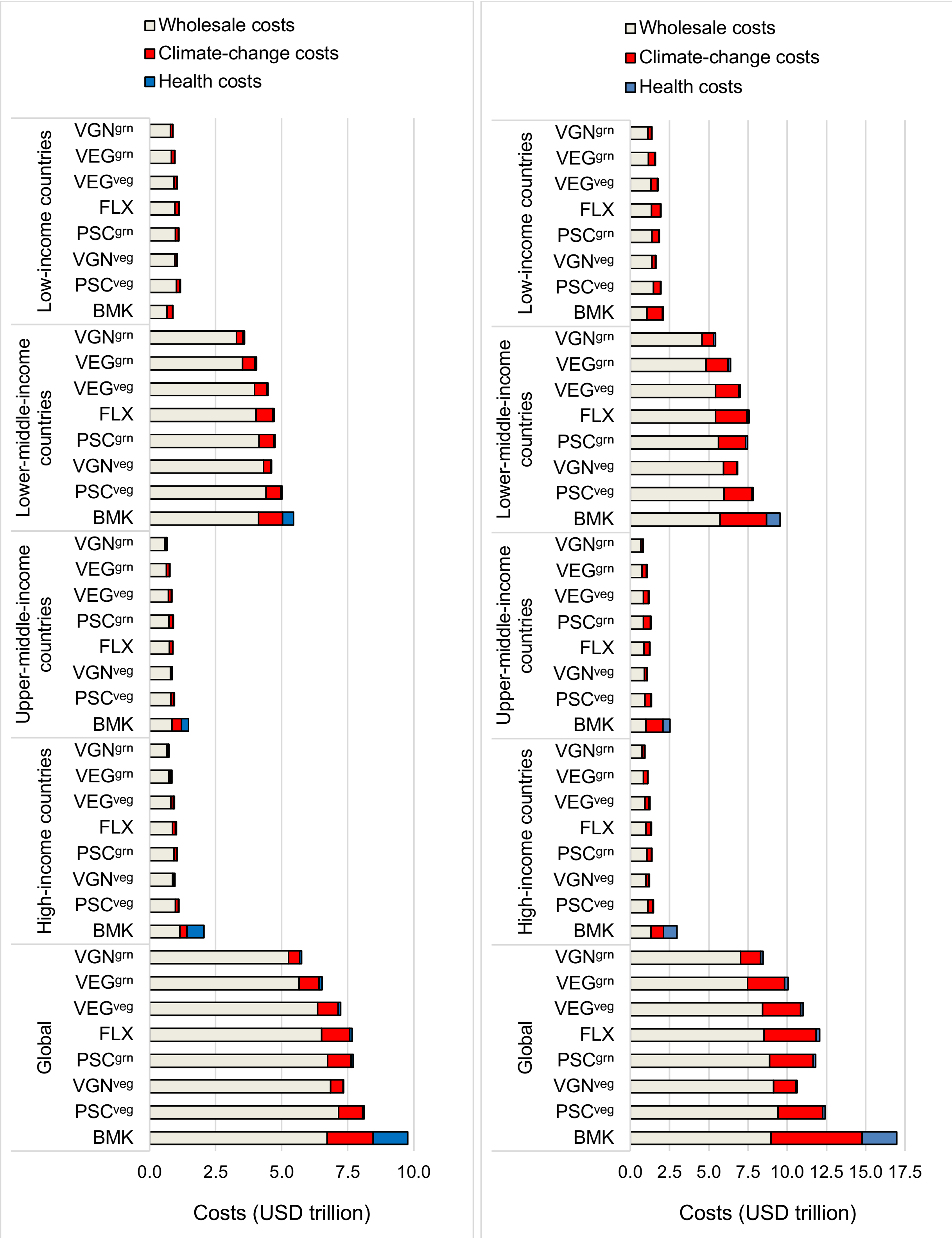
**Figure 7. Total costs of diets (USD trillion) by cost component, year and region**




Source: Author's own elaboration.

In 2050, the opposite reasons led increases of 34 percent, 68 percent, and 234 percent for wholesale costs, health costs, and climate-change costs, respectively, indicating a disproportional increase in the latter two cost items. The costs of climate change alone were at equal level with the wholesale costs of diets in upper-middle-income and low-income countries, and together with health costs would exceed them in high-income and upper-middle-income countries. Adoption of the more plant-based dietary patterns led to reductions in the full cost of diets of 27–50 percent on average, ranging from 98–36 percent in low-income countries to 51–68 percent in high-income countries, with greatest reductions for the more plant-based dietary patterns (Figure 8).

**Figure 8. Total costs of diets (USD trillion) in 2030 (left) and 2050 (right) by dietary pattern, cost component and region**




Note: The diet scenarios include baseline/benchmark diets (BMK), flexitarian diets (FLX), as well as pescatarian (PSC), vegetarian (VEG), and vegan (VGN) diets, each in high-veg (veg) and high-grain (grn) variants (Table 1).

Source: Author's own elaboration.

## 4 Conclusion

The health and climate-change costs of current and projected diets are substantial, and projected to increase. Internalising the health and climate-change costs of diets into a "full cost of diets" would make these reductions visible to the consumer and allow for more informed consumption choices. Whilst the full costs of current diets would increase, our analysis suggests that healthier and more sustainable diets would be become relatively more affordable under full-cost accounting, because they are associated with significantly lower external costs. However, support for poor countries and households might be needed to avoid some of the potentially negative consequences of higher food prices (Springmann *et al.*, 2017, 2018b).

Our study advances the current understanding of the health and environmental externalities of the food system. It extends a previous valuation by increasing the number of dietary risk factors covered in the health analysis and valuation, using more recent emissions data in the environmental analysis, and using a larger and standardised set of healthy and sustainable dietary patters.

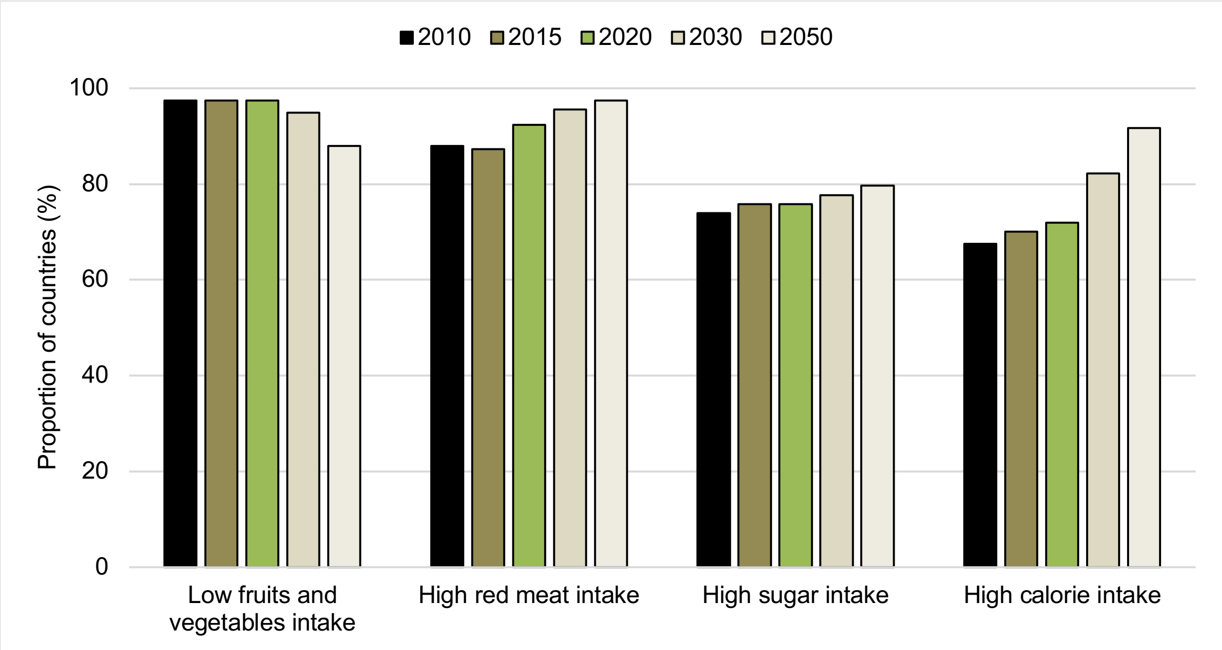
However, our study is also subject to several caveats. Our account of the health and climate-change costs is subject to high uncertainty and does not capture all the currently unaccounted impacts of the food system. In the health-cost analysis, we had to rely on a cost-transfer method that adjusted base costs that were measured for one region for changes in income and health expenditure to derive health-cost estimates for regions and years (Springmann *et al.*, 2016). Broadening efforts to expand and standardise cost-of-illness assessments at a regionally comparable level would significantly improve the evidence base.

In our analysis of the costs of climate change, we used estimates of the social cost of carbon that are both model-dependent and highly variable, e.g. when considering different rates of discounting future climate-change costs to a present value (Nordhaus, 2017). We aimed to reduce uncertainty by using model estimates that were in line with stated policy objectives and using market-based discount rates. However, many uncertainties remain, including the feedback between changes in temperature and economic growth,(Burke, Hsiang and Miguel, 2015) the rate of climate-change adaptation and mitigation (Moore and Diaz, 2015). In addition, there are many other impacts of the food system that are currently not reflected in the prices, including biodiversity impacts and water pollution (Willett *et al.*, 2019).

Our comparison to the basic cost of diets did not reflect final retail prices of consumer end products, but was instead based on wholesale prices of basic food commodities which were available at a comparable basis. Differentiated mark-up rates at the retail level and inclusion of processed foods, which often carry substantial price premiums, can lead to substantial differences between wholesale and final costs of diets. A sensitivity analysis with a limited set of final consumer prices confirmed this, but indicated similar trends across regions and diet scenarios as identified in our main analysis. We encourage the collection and public release of more comprehensive and regionally comparable price data at the retail level to allow for comparison and updates to studies like this one.

Although incorporating external costs into the price of foods can contribute to dietary changes towards healthier and more sustainable diets, previous analyses suggest that price incentives alone might not be enough to achieve the scale of dietary changes needed (Springmann *et al.*, 2017, 2018b). For example, only 5 percent of all countries are projected to meet the target values for fruits and vegetable and for red meat of the least stringent diet modelled here, the flexitarian diet, by 2030, whilst about 80 percent would not meet recommendations on curtailing excessive energy and sugar intake (Figure 9).

**Figure 9. Proportion of countries not meeting the target values of the least stringent of the healthy and sustainable dietary patterns (the flexitarian diet) by risk factor and year**




Source: Author's own elaboration.

Additional policy measures that could incentivise a greater uptake of healthy and more sustainable diets include a combination of media and education campaigns; labelling and consumer information; additional fiscal measures, such as taxation, subsidies, and other economic incentives; school and workplace approaches; local environmental changes; and direct restriction and mandates (Mozaffarian *et al.*, 2012). An important first step would be to align national food-based dietary guidelines with the current evidence on healthy eating and the environmental impacts of diets (Springmann *et al.*, 2020).

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