Summary of dataset

A dataset of per unit environmental external costs from greenhouse gas (GHG) emissions, blue water withdrawal, nitrogen losses, and land-use transitions to and from cropland and pasture, and labour productivity costs of non-communicable diseases per unit of exposure to dietary risk such as low per capita fruit and vegetable consumption.

The format of the dataset and accompanying files are described alongside brief information on the use and scope of the cost estimates. More information on use and scope, the calculation approach, and validation are given in the report at https://ora.ox.ac.uk/objects/uuid:4ae3f458-68c4-402c-9a8a-9ed7abf8cca8 . The report further refers to the documentation of the SPIQ-FS model on which the calculations are based. The report has a summary of studies and evaluations which used previous versions of the dataset.

The publishing of the dataset satisfies Deliverable 1.3 under Work Package 1 of the 2022-2026 EU Horizon Europe project FOODCoST for an "EU-global database on externality costs including an open-source dataset of national external cost values".

Metadata

Title of the dataset

"FOODCoST global dataset of national per unit costs of environmental externalities and dietary risk internalities associated to food system activities under the SSPs"

Shorter version

"FOODCoST global dataset of per unit costs under the SSPs"

Shortest version

"FOODCoST SSPs Dataset"

Citation

Steven Lord and Shaun Solomon. "FOODCoST global dataset of national per unit costs of environmental externalities and dietary risk internalities associated to food system activities under the SSPs". Environmental Change Institute. University of Oxford. (2025). Version 0.2. Available at: https://ora.ox.ac.uk/objects/uuid:7c116abc-92fe-4725-ad38-aaa5ff68bef5

Availability

A folder containing 5 comma-separated values (CSV) files and 1 text file with UTF-8 encoding. Commas (UTF-8 0x2C) are separators in the .csv and periods (UTF-8 0x2E) are decimal points. The _S variant of the folder contains Monte Carlo samples. The _S variant of the folder is a larger download (1 GB) than the parametric version without samples (3 MB).

Download link: https://ora.ox.ac.uk/objects/uuid:7c116abc-92fe-4725-ad38-aaa5ff68bef5

Dataset

SPIQ_Marginal Cost_FOODCOST_Data_E.csv (or SPIQ_Marginal Cost_FOODCOST_Data_E_S.csv)

SPIQ_Marginal Cost_FOODCOST_Data_H.csv (or SPIQ_Marginal Cost_FOODCOST_Data_H_S.csv)

Accompanying Files

B: SPIQ_Marginal Cost_FOODCOST_Cost.csv

C: SPIQ_Marginal Cost_FOODCOST_Ctry.csv

D: SPIQ_Marginal Cost_FOODCOST_Proj.csv

E: License.txt

License

The License .txt file contains the following text.

> This work is licensed under Creative Commons Attribution-ShareAlike 4.0 International (CC-BY-SA 4.0) *with the following exception.* For license terms visit http://creativecommons.org/licenses.
>
> *The dataset in the file "SPIQ_Marginal Cost_FOODCOST_Data_H.csv" specifying per unit cost of dietary risk internalities is licensed under Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC-BY-NC-SA 4.0). Data to determine the per unit cost of dietary risk internalities includes data obtained from IMHE https://ghdx.healthdata.org, which has a non-commercial user agreement https://www.healthdata.org/Data-tools-practices/data-practices/ihme-free-charge-non-commercial-user-agreement. Users of the dataset should clarify intended use with the IMHE non-commercial user agreement.*

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Description

Use

For estimates of economic risks arising from environmental externalities and dietary risk internalities of food system activities. Estimates can be used in cost-benefit assessment of the economic potential of transforming EU and global food systems.

Impact quantities

Co-products of food system activities that result in externalities or internalities that could lower future gross product (Table 1). Examples include metric tons of carbon dioxide emissions that results in future agricultural productivity losses or labour productivity from heat stress due to the radiative forcing of the emitted carbon dioxide, and exposure to current unhealthy patterns of dietary consumption in the population that lowers future labour productivity. 12 impact quantities associated to environmental externalities and 15 impact quantities associated to dietary risk internalities are covered. For convenience, the first 3 columns of Table 1 concerning impact quantities are tabled in the accompanying file B.

Cost

To future gross product in purchasing power terms per additional unit of impact quantity. Measured in present purchasing power in 2020 (2020 PPP).

Spatial coverage

Estimates of per unit cost for Table 1 impact quantities are provided for 153 countries. The list of countries and administrative data are provided in accompanying file C. For convenience countries are identified in the dataset

by: name according to the country names used in the World Integrated Trade Solution (WITS) and World Development Indicators (WDI) databases of the World Bank; unique ISO 3166-1 alpha-3 code, and; United Nations (UN) numerical classification system of sovereign countries and territories number.

The first 3 columns of the dataset .csv files provide the country identifiers.

CountryName	Country names used by the World Bank https://wits.worldbank.org/wits/wits/witshelp/content/codes/country_codes.htm
CountryCode	ISO 3166-1 alpha-3 country code https://www.iso.org/iso-3166-country-codes.html
M49	UN numerical classification system of sovereign countries and territories https://unstats.un.org/unsd/methodology/m49/

Temporal coverage

Covers production of Table 1 impact quantities over the period 2020 to 2050 in 5-year timesteps under 5 Shared Socioeconomic Pathways. More information about the SSPs and future projections is discussed in the Approach.

Columns 4-5 of the datasets indicate the year of production of the impact quantity (an emission, withdrawal, loss, land clearance, or consumption) and the future scenario assumed.

Year	2020, 2025, 2030, 2035, 2040, 2045, 2050	
Scen	1	SSP1-RCP2.6. **SSP1: Sustainability (Taking the Green Road):** Focuses on inclusive development and sustainable practices. High cooperation and reduced inequality lead to better environmental outcomes. **RCP2.6**: Ambitious mitigation with strict climate action. Below 2 degrees of warming by 2100 above pre-industrial baseline.
	2	SSP2-RCP4.5. **SSP2: Middle of the Road:** Represents a moderate path with balanced socioeconomic progress and challenges continuing current trends. Inequalities persist but are not extreme, and policy developments are incremental. **RCP4.5**: Moderate efforts to stabilize emissions. Policies support gradual shifts. Between 2-3 degrees of warming by 2100 above pre-industrial baseline.
	3	SSP3-RCP6.0. **SSP3: Regional Rivalry (A Rocky Road):** Depicts a fragmented world with regional tensions, slow economic growth, and limited climate action, leading to high vulnerability to climate change. **RCP6.0**: Limited action and slower transitions. Market-driven technological developments. Above 3 degrees of warming by 2100 above pre-industrial baseline.
	4	SSP4-RCP7.0. **SSP4: Inequality (A Road Divided):** Highlights a world of stark inequalities. Affluent regions thrive while poorer areas struggle, exacerbating social and environmental problems. **RCP7.0:** Baseline. Above 3.5 degrees of warming by 2100 above pre-industrial baseline.
	5	SSP5-RCP8.5. **SSP5: Fossil-Fueled Development (Taking the Highway):** Prioritizes economic growth with heavy reliance on fossil fuels, leading to high greenhouse gas emissions and environmental degradation. **RCP8.5**: Minimal policy, continued high emissions. Above 5 degrees of warming by 2100 above pre-industrial baseline.

For example, a metric ton of carbon dioxide emitted in 2035 (Year) under SSP2 (Scen) in Zambia (Country) is costed for its future impact after 2035 due to additional radiative forcing in the SSP2-4.5 scenario. The SSP2 GDP and population projections are used to discount the future purchasing power losses to 2020 PPP. Another example is a kilogram of nitrogen in the form of ammonia is volatilized to air from synthetic fertilizer applied to cropland in Belgium in 2050 under SSP3-6.0. Cost estimates use SSP3-6.0 projections for precursors to particulate matter formed from volatilized ammonia, including NOx emissions, SOx emissions, population density and average temperature, GDP, and demographics to estimate the additional disease outcomes from the air pollution and the value of lost labour. SSP3 GDP and population projections are used to discount the future purchasing power losses to 2020 PPP.

Each SSP and RCP combination portrays distinct trajectories of societal development, cooperation, climate policy and environmental impact. To assist users to match the 5 SSP-based future projections to a user customized future scenario, the accompanying file D lists some of the projections used in the cost modelling including GDP (in fixed 2020 international dollars), population density, percentage of the population over 65 years of age, urbanisation, industrial pollution, and human development index, for the 153 countries in the 5-year timesteps of 2020 to 2050 for the 5 SSPs.

Quantity and units

Columns 6-8 of the datasets indicate which impact quantity from Table 1 and the unit of the marginal cost. Unit 2 is 2020 PPP. Unit is the unit of the impact quantity. The unit of the cost per unit is Unit2 per Unit.

Quantity	Impact quantities. Listed in Column 2 of Table 1
Unit2	Economic unit. 2020 PPP.
Unit	Impact quantity units. Listed in Column 3 of Table 1

Value and uncertainty

Cost per additional unit is modelled as a random variable. The datasets provide the random variable in parametric and non-parametric forms. Column 9 provides the mean value of the cost per unit.

Mean	Mean value of 1000 samples of the cost per unit generated by the SPIQ-FS cost models

Parametric form

Columns 10-11 contain two parameters for the per unit cost treated as a log-normally distributed random variable. The evidence and practicality for treating the per unit cost as log-normally distributed is discussed in the approach. Samples of the per unit cost can be generated from sampling a normal distribution of mean Mu and standard deviation Sigma. Exponentiating (base e) the resulting samples gives samples of the per unit cost.

Mu	Mean value of log(X) where X is cost per unit and log is the natural logarithm
Sigma	Standard deviation of log (X) where X is cost per unit and log is the natural logarithm

The values are negative for dietary risks with underexposure. The parameters Mu and Sigma are then defined by -X. The mean of the samples reconstructed from the parametric form will deviate from the mean in Column 9, mainly because of the chance of outliers from a log-normal distribution and slightly due to adjustments in the cost models between parametric forms and final values. By design, the mean in Column 9 matches the mean of the non-parametric empirical distribution represented by samples in Column 12.

Non-parametric form

Column 12 provides 1000 samples from a joint empirical distribution of the cost per unit random variables. At present in the SPIQ-FS model correlations are embedded most strongly between impact quantities, e.g. where future climate change having a larger impact and higher cost than average could correlate with more significant impact and losses from land-use change or water scarcity (Quantity), weakly over countries where aspects such international trade disperses price impacts of lost agricultural production (Country), and more weakly over years within scenarios (Year, Scen).

Samples	Each column represents a joint sample of the per unit cost across impact quantities, countries, years and scenarios.

The parametric form can only reconstruct the marginals of the underlying joint empirical distribution represented by the samples and not the correlation structure.

Other central measures can be calculated from marginal Samples. Generally, the cost per unit marginals are skewed, so the mean can be significantly higher than the median and mode.

Aggregation

Aggregating across quantities includes the assumption of substitutability across natural, human and produced capital, and risks potential double-counting. One reason to limit the number of impact quantities is the risk of double-counting. The first 25 impact quantities in Table 1 are designed to be additive, bar the caveats on substitution and potential double counting mentioned. Cost of diets low in fibre and low in milk have significant overlaps with diets low in fruits, vegetables, whole grain, legumes and calcium. Fibre and milk are included for separate consideration.

When aggregating across countries, years, or quantities additional care must be taken with the parametric form. The sum of two normally distributed random variables is normally distributed, but the sum of two log-normally distributed random variables is not log-normally distributed and its distribution is not well approximated by a log normal distribution as a general case. The Mean and the Samples are additive, but the parameters Mu and Sigma are not. Other central measures are not additive if significantly different than the mean.

Limitations

Limitations to the cost estimates and omissions from the list of impact quantities are discussed under Use and Scope, and Approach, in the accompanying text.

Tables

Table 1. Input quantities with corresponding marginal costs per unit and indicative activities

Cost category	Impact quantity	Unit	Type	Marginal cost	Examples of activities
GHG emissions	CH_4 emission	metric ton (t)	Environmental externality	Social cost of CH_4: residual damages to global future GDP PPP (in NPV in 2020) from contribution to climate change at the optimal amount of abatement, attributed to the country of emission	Enteric fermentation in livestock, methanogens in flooded rice fields, organic waste in landfill
GHG emissions	CO_2 emission	metric ton (t)	Environmental externality	Social cost of CO_2: residual damages to global future GDP PPP (in NPV in 2020) from contribution to climate change at the optimal amount of abatement, attributed to the country of emission	Fertiliser production, cold-chain storage, shipping commodities, consumer food preparation, loss of soil carbon
GHG emissions	N_2O emission	metric ton (t)	Environmental externality	Social cost of N_2O: residual damages to global future GDP PPP (in NPV in 2020) from contribution to climate change at the optimal amount of abatement, attributed to the country of emission	Volatilization from manure, applied fertiliser, and soils. Secondary emission from N losses to the environment
Water use	Blue water withdrawal	cubic metre (m3)	Environmental externality	Future costs to agricultural productivity and labour productivity (in NPV in 2020) from non-renewable water consumption and the reduction of water resources for economic use, attributed to the country of withdrawal.	Irrigation
Land-use change	Forest habitat loss	Hectares of habitat lost (ha)	Environmental externality	Value of effective hectares of present and future lost ecosystem services (in NPV in 2020) in the country of land-use transition due to the destruction or degradation of forest ecosystem	Deforestation to clear land for palm oil plantations or livestock grazing
Land-use change	Forest habitat return	Hectares of habitat returning (ha)	Environmental externality	Value of effective hectares of present and future returned ecosystem services (in NPV in 2020) in the country of land-use transition due to recovery or re-establishment of ecosystem	Abandoned agricultural land reforestation. Afforestation on agricultural land
Land-use change	Other natural habitat loss	Hectares of habitat lost (ha)	Environmental externality	Value of effective hectares of present and future lost ecosystem services (in NPV) in the country of land-use transition due to the destruction or degradation of other natural land ecosystem	Conversion of wetlands to cropland or natural grassland to high density livestock pasture
Land-use change	Other natural habitat return	Hectares of habitat returning (ha)	Environmental externality	Value of effective hectares of present and future returned ecosystem services (in NPV in 2020) in the country of land-use transition due to recovery or re-establishment of ecosystem	Marginal agricultural land abandoned and returning to natural state
Nitrogen losses	NH_3 loss to air	Mass of NH3 that contains 1 kg of nitrogen (N-kg)	Environmental externality	Productivity losses (in NPV in 2020) in the country of emission due to the burden of disease from particulate matter formation, agricultural and ecosystem service losses from nutrient	Ammonia volatilization from manure left on pasture and application of fertilizer

Cost category	Impact quantity	Unit	Type	Marginal cost	Examples of activities
				imbalance and the acidification of terrestrial biomes due to deposition, ecosystem services losses from nutrient imbalance, acidification and eutrophication of riverine, wetland and coastal systems due to deposition runoff	
Nitrogen losses	NO_x loss to air	Mass of NO_2 that contains 1 kg of nitrogen (N-kg)	Environmental externality	Productivity losses (in NPV in 2020) in the country of emission due to the burden of disease from particulate matter formation, agricultural and ecosystem service losses from nutrient imbalance and the acidification of terrestrial biomes due to deposition, ecosystem services losses from nutrient imbalance, acidification and eutrophication of riverine, wetland and coastal systems due to deposition runoff. Agricultural losses from release of surface level ozone.	Release of nitrogen oxides from burning of fossil fuels in farm machinery and transport. Burning of crop residues. Manure and fertilisers
Nitrogen losses	NO_3- loss in runoff from agricultural land	Mass of NO_3- that contains 1 kg of nitrogen (N-kg)	Environmental externality	Ecosystem services losses (in NPV in 2020) from nutrient imbalance, acidification and eutrophication of riverine, wetland and coastal systems due to nitrate load in surface water	Manure left on pasture and surplus fertilizer
Nitrogen losses	NO_3- loss in soil leaching on agricultural land	Mass of NO_3- that contains 1 kg of nitrogen (N-kg)	Environmental externality	Ecosystem services losses (in NPV in 2020) from nutrient imbalance, acidification and eutrophication of riverine, wetland and coastal systems due to nitrate load in surface water (from subsurface flows emerging into surface water) and productivity losses in the country of emission due to the burden of disease from human nitrate intake in drinking water from groundwater.	Manure left on pasture and surplus fertilizer
Dietary patterns (high in processed foods and additives)	Diet high in processed meat	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from overexposure, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes.	Overconsumption in the national population.
Dietary patterns (high in processed foods and additives)	Diet high in sugar-sweetened beverages	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from overexposure, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Overconsumption in the national population.
Dietary patterns (high in processed foods and additives)	Diet high in sodium	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from overexposure, predominantly, stomach cancer. Does not include effects on systolic blood pressure.	Overconsumption in the national population.
Dietary patterns (high in processed foods and additives)	Diet high in trans fatty acids	% of energy intake /capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from overexposure, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Overconsumption in the national population.

Cost category	Impact quantity	Unit	Type	Marginal cost	Examples of activities
Dietary patterns (consumption of animal whole foods)	Diet high in red meat	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from overexposure, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Overconsumption in the national population.
Dietary patterns (consumption of animal whole foods)	Diet low in milk	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in plant whole foods)	Diet low in fruits	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in plant whole foods)	Diet low in vegetables	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in plant whole foods)	Diet low in whole grains	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in plant whole foods)	Diet low in legumes	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in plant whole foods)	Diet low in nuts and seeds	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in beneficial fatty acids)	Diet low in polyunsaturated fatty acids	% of energy intake /capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in beneficial fatty acids)	Diet low in seafood omega-3 fatty acids	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in essential nutrients)	Diet low in calcium	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.
Dietary patterns (low in essential nutrients)	Diet low in fibre	g/capita/day	Dietary risk internality	Productivity losses (in NPV in 2020) in the country of consumption due to the burden of disease from, predominantly, cardiovascular disease, neoplasms, and type-2 diabetes	Underconsumption in the national population.

Notes: CO_2 = carbon dioxide; CH_4 = methane; DALYs = disability-adjusted life years; N = nitrogen; N_2O = nitrous oxide; NH_3 = ammonia; NO_x = nitrogen oxides; NO_3- = nitrate; NPV = net present value; PPP = purchasing power parity. Marginal costs of diet low in essential nutrients (calcium and fibre) are not compatible with diet low in food-group based estimates.