SPIQ-FS Version 0 Dataset

Notes on the SPIQ-FS Generic Dataset Version 0

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Summary

Technical note on the SPIQ-FS Generic Dataset for 14 Marginal Cost items and 158 countries as a supplemental to Annex A and Annex B Documentation. Annex Z of this document provides metadata for the columns in the SPIQ-FS Generic Dataset .csv file.

Methodology

Costs are estimated by multiplying changes in greenhouse gas (GHG) emissions and other quantities associated to external costs and market failures in food production and food consumption against their marginal damage costs (Annex S). Change in GHG emissions and other quantities can be positive or negative, and the cost analysis indicates either incurred damages or avoided damages respectively.

Notes on cost assumptions

Quantities

It is assumed that the quantity changes provide a counterfactual global environment state and economy of 2020. It is assumed that the status quo and counterfactual worlds share the shared socio-economic future SSP2 [1] after changes.

Marginal damages

Marginal damage costs for the 158 countries are calculated using the SPIQ-FS version 0 marginal damage cost model developed for the Food System Economic Commission [2-6]. Damages from GHG emissions, nitrogen emissions, habitat loss or return from land-use change, water withdrawals, poor livelihoods, and undernourishment attributed to the agricultural subsidy change are incurred or avoided in the counterfactual and its future economies. Damage to future economies is estimated using future projections for IPPC shared socioeconomic pathway SSP2 [7]. SPIQ-FS version 0 makes estimates in USD PPP 2020 (international dollars [8, 9]) of marginal damages per unit. Annex S (the generic SPIQ-FS dataset version 0) lists the units for quantities and the damages costs generated by the SPIQ-FS model.

Total damages

Quantities and their marginal damage costs are multiplied to obtain country level totals for disaggregated quantities (Annex T).

Damage costs for all countries are measured in 2020 USD PPP (Purchasing Power Parity), also known as 2020 International Dollars, [8, 9]. Purchasing power parity represents the equivalent amount of a basic goods basket in 2020 that $1 USD, once exchanged to local currency, purchases in that country. The goods represent welfare provided by their consumption. Damage costs measured in $2020 USD PPP represent the reduction in welfare due to reduced purchasing power and avoided damage costs represents the benefit in an avoided reduction in welfare.

The damage costs calculated in 2020 USD PPP, positive and negative, reflect the change (a reduction or an avoided reduction, respectively) in the amount welfare provided by basic goods in the counterfactual.

External costs and market failures

The damage costs do not reflect the full economic costs of the policy change. They should be compared to GDP PPP changes to compare the welfare changes from produced capital against potential damages from externalised costs factoring through human and natural capital that are not reflected in ordinary economic modelling. The damages calculated represent changes in the "the hidden costs" as colloquially used by FSEC [10] in the counterfactual.

A subsequent analysis is required to compare the visible economic costs in the counterfactual from the change with the value from reduced damages.

Notes on marginal cost calculations

SPIQ-FS refers to the SPIQ-FS version 0 model documented here, [2-6]. An overview of the SPIQ-FS cost models is available in [11].

Costing GHG emissions

SPIQ-FS resamples IWG-SCGHG simulations of the social cost of greenhouse gases in 2020 [12, 13]. IWG-SCGHG simulations are provided for three discount rates (2.5%, 3% and 5%) and five socio-economic scenarios used by integrated climate modelling groups to inform IPCC reports, [12]. Using national GDP growth projections for SSP2 to 2100 [7] global rates matched a discount rate of 3% - this was used for the social cost of greenhouse gases resampling. A Ramsey social discount rate is assumed with time preference of 0 and constant elasticity of marginal utility of 1.5 [14, 15]. Given the 3% discount rate, social costs under the five scenarios were sampled uniformly for additional uncertainty estimates of economic futures under SSP2. Social costs represent marginal damage costs under a future pathway of optimal economic abatement [16].

IWG-SCGHG simulations provides social costs for emission of a metric ton of CO_2, CH_4 and N_2O. CO_2-equivalents are not used, and the gases are costed separately. Converting to CO_2e and multiplying by the social cost of CO_2 would underestimate the total damages, since CH_4, in particularly, has shorter term effects and future damages due to CH_4 are less discounted [17-19].

Costs of a GHG emission in a country are borne globally through the global atmospheric and then climatic changes. To attribute the cost of an emission as a cost to the country that made the emission, it is assumed that economic actors in that country are required to pay an amount per emission equal to the social cost of the respective GHG, and that the amount paid is dispersed perfectly to the cost-bearers in PPP terms from the emission inside or outside the country.

Costing water withdrawals

SSP2 discount rates were used for impacts of future water scarcity. Given no comprehensive global spatial estimates of the temporal allocation of water resources deprived from economic use under SSP2 from a spatially explicit water withdrawal in 2020 [20], the costing model uses a Poisson process [21] to temporally allocate national effects of water withdrawal in 2020 [4].

Marginal damages for water withdrawal are underestimates due to lack of data on accrued loss from water scarcity and damages from loss of environmental flows [22].

Costing land use changes

Costs of land use changes in terms of lost, retained, or returned ecosystem services are derived from the Ecosystem Service Valuation Database (ESVD) [23, 25]. Valuations are given in ha/yr. How many years into the future ecosystem services are lost or provided after land use changes at a given time is an additional modelling consideration [26-28]. No changes in services after a transition were assumed up to 2100. This is a simplification. Transition in land use can occur from forestry or agricultural use, abandonment, and then return to forestry or agriculture use. For abandoned land, evidence suggests an average of 14 years of returned ecosystem services [29]. The value of the services in future years can also change due to changes in the supply and demand for ecosystem services, resulting in so-called environmental discount rates [30]. Environmental discount rates were not used. National level discount rates to 2100 under SSP2 [7] used to discount 80 years of lost ecosystem services from 2020 to 2100 at a constant value in ha/yr, and obtain cumulative values for a ha of land use change.

The SPIQ-FS generic dataset considers four categories of land-use transition.

Forest habitat loss refers to deforestation or avoided deforestation. This is treated as a loss or retention, respectively, of forest ecosystem services. Many economic models on forest habitat change does not distinguish between tropical and temperate forest habitat. Marginal costs for ha of land use change from the SPIQ-FS model described in Annex A and the Ecosystem Services Valuation Database distinguish between tropical and temperature forests. ESVD uses the TEEB Classification and CICES (v5.1) classification systems of ecosystems and services [31, 32]. To reconcile cost and quantity categories from economic models, a marginal cost for ha of forest habitat change was sampled randomly from tropical and temperate marginal cost samples in proportion to national tropical and temperature forest historical areas. For countries crossing tropical and temperate latitudes this is an approximation in the absence of a historical dataset of tropical and temperate forest transitions to agricultural use.

Economic models also provides conversion or avoided conversion of Other Land Habitat. Other Habitat is assumed to coincide with shrubland, woodland, grassland, and unmanaged rangeland terrestrial land classifications in the Ecosystem Services Valuation Database. The Ecosystem Services Valuation Database has few valuations in these categories even when national estimates are aggregated into Human Development Index brackets. Global spatial datasets of land area and land transitions for habitats, such as the WWF ecoregions dataset (https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world) and the HILDA+ transitions dataset [33], do not distinguish between grassland and shrubland. For this study, the ecosystem service samples for these habitats are combined in SPIQ-FS, to create a national level cost quantity for Other Habitat to match economic modelling. The costing is conservative, as it excludes conversion or avoided conversion of inland wetlands and coastal wetlands such as mangroves for crops such as rice and palm oil [34].

The final component is abandoned cropland and pasture. We assume this represents a transition of cropland and pasture to Forest or Other Habitat. The provision of services from abandoned land can be of lower value than intact ecosystems [29, 35], with previously forested areas progressing through regenerative stages of grassland, shrubland and then reforestation [36, 37]. Historically, land may transition back within decadal time spans [29]. Given the nature of progressive stages of regeneration of both ecosystem and ecosystem services, we assume services provided by abandoned cropland and pasture return at a linear rate to an equivalent ha of forest or unmanaged grassland after 20 years [35, 37, 38].

Emissions from land-use change are usually counted under GHG emissions. The ESVD database includes carbon sequestration as an ecosystem service valuation. Carbon sequestration services were excluded to the degree possible from the valuation of service per ha estimated from the ESVD to avoid double counting.

Costing nitrogen use changes

The SPIQ-FS version 0 nitrogen emissions costing model estimates marginal damages from volatilization of NH3 (ammonia) and NOx (nitrous oxides) to air, and run-off of reactive nitrogen into surface waters and soil leaching, predominately soluble NO3- (nitrate). Economic losses occur through labour productivity losses from air pollution, crop losses, and loss of ecosystem services [3]. Spatial datasets on ecosystem distribution, population density, average temperate, deposition, and riverine transport, are used to transfer marginal damages derived from the European Nitrogen Assessment [39, 40].

Costing undernourishment

The quantity for this costing is headcount within a national population with food intake below minimum energy requirements as defined by the FAO [41]. SPIQ cost modelling includes a model for 2020 from headcount of undernourished (NOU), to Disability Adjusted Life Years lost (DALYS, [42-44]) from energy-protein malnutrition [45]. The productivity losses of energy-protein malnutrition are costed using historical ILO labour productivity data (https://ilostat.ilo.org/data/). Labour productivity is used in place of GDP per capita to account for caring burden of young and old age dependents in households.

Costing poverty

The quantity for this costing is headcount of extreme poverty, defined for 2020 by the World Bank as an income below $1.90/day (2011 PPP).

Data on the $1.90/day (2011 PPP) national poverty gap over 2014-2019 was downloaded from the World Bank [https://data.worldbank.org/indicator/SI.POV.GAPS]. Poverty gaps were converted into average income shortfall per annum and adjusted by inflation in PPP terms to 2020 PPP.

Projections of changes in the annual income shortfall under SSP2, since it is a conditional average of the income distribution below the extreme poverty threshold, accounts for both the changing income of the extreme poor, and the background shift of individuals out of extreme poverty. To understand the accrued PPP income shortfall for an increase of one individual in extreme poverty in 2020 due to the policy intervention, the income shortfall per annum of the individual needs to be projected forward and then discounted.

Average income shortfall per annum was projected to 2023 alongside World Bank GDP projections using a equidistributed pass through rate https://blogs.worldbank.org/opendata/projecting-global-extreme-poverty-2030-how-close-are-we-world-banks-3-goal . Projection of income shortfall per annum after 2023 used SSP2 GDP projections https://www.sciencedirect.com/science/article/pii/S0959378015000242 to 2100 and equidistributed pass through rate.

The series of annual income shortfall reduction obtained was multiplied by the cumulative discount rates for SSP2 and summed to approximate the total marginal cost of an increase of one individual in extreme poverty in 2020 in the counterfactual. Uncertainty in the accrued income shortfall of one additional individual in extreme poverty in 2020 was sampled by using historical variance in national real GDP growth and uncertainty in time preference in the social discount rate (sampled uniformly in the range [0,0.01]) for income shortfall.

The total cost of poverty from an intervention is defined as the difference in income-equivalent welfare required to eliminate changes in extreme poverty attributable to the intervention. The income-equivalent welfare required is the extreme poverty headcount change in the counterfactual multiplied by the accrued average income shortfall in PPP terms.

Estimates of economic risk

Marginal costs in the SPIQ-FS generic dataset are provided with uncertainty estimates in the form of parameterised probability distributions [2-5]. This provides uncertainty estimates in the total cost for quantity changes in each category due to policy changes (e.g. costs due to changes in GHG, costs due to changes in water withdrawal, costs due to changes in undernourishment). SPIQ models some damage costs jointly within categories based on historical data. The impact of the integrated nature of changes in environmental, health, and social conditions on economic costs when totalled across categories is reflected in SPIQ-FS by correlation in damage costs across categories.

Total estimates of the economic damages from policy changes resulting from changes in environmental pollutants and resources, dietary intake, and poverty, are derived from jointly sampling marginal costs. Three sets of correlations are used to explore the joint nature of environmental, health and social conditions on total economic costs: no correlation, an expert derived set of correlations, and perfect correlation.

These three representations in risk from joint effects can be used to contrast ignoring joint effects of environment and health with the case where higher than expected environmental damage costs will always coincide with higher than expected health damage costs. The middle, expert-derived, set of correlations represents a best estimate of the additional economic risk from joint effects.

When comparing policy scenarios to each other or a status quo, where changes increase some damages and reduce others, the uncertainty estimates work both ways in terms of costs incurred, or costs saved. The full distribution of change in total economic costs may reflect risk in moving from the status quo, as well as risk in staying with the status quo.

Limitations

GHG social cost modelling relies on the 2020 update to the US EPA IGWG-SCGHG simulations, which originated from modelling in 2011 and a 2016 update.

Water cost modelling is limited by a lack of data on magnitude and time in the future of the deprivation of water for use in the production of economic value due to a water withdrawal in the present. Cost estimates are not catchment based, which is a future improvement. Damages from reduced environmental flows are not calculated from lack of data. National aggregation is used, and transboundary effects are not included. Water cost estimation is conservative to account for limitations.

Nitrogen cost modelling involves benefit transfer from the European Nitrogen assessment accounting for national variation in temperature, population density, background non-agricultural NH_3, NO_x, and SO_x emissions. The transfer for NH_3 and NO_x uses additional data from the EASIUR model of over 3000 US counties [46]. Errors in transfer are the basis for uncertainty modelling. Variation in the value of ecosystem services is large and introduces additional uncertainty in calculations of deposition and run-off. The large uncertainty in the results below for nitrogen and land-use change reflect the uncertainty introduced by benefit transfer and lack of knowledge on the value of ecosystem services.

Undernourishment is based on loss of productivity from WHO estimates of DALYs due to protein-energy malnutrition [45]. Other lost productivity or later-life socio-economic consequences of undernourishment are not included. By the World Bank definition of extreme poverty [47], it is eliminated by transfer of the income shortfall to the extreme poor. Extreme poverty does not incorporate all economic consequences of income inequality.

The economic measure of hidden costs is loss of welfare from reduced purchasing power. This measure is suitable for use in national accounts. It can be incorporated in social welfare functions but is a limited measure of social welfare. Lost intangible value is reflected indirectly in consequences for present or future economies in the measure of value to humans discovered through the exchange of goods and services on visible markets. Risk in the delay, or lack, of transmission of present intangible value into visible markets is not accounted for.

Quantities

Quantities associated to impact provide the cost categories of the marginal cost items.

3 categories relate to direct emission of CO_2, CH_4, and direct or indirect emission of NO_2.

4 categories relate to land-use transition of forest habitat, and other land habitat, as described in the Methodology section.

4 categories relate nitrogen emissions of volatilized NH_3 and NO_x and run off or leaching of Nr.

1 category of blue water use withdrawal

The social indicators of undernourishment, as defined by the FAO prevalence of undernourishment indicator, and extreme poverty as defined by the World Bank, provide 2 categories.

Table 1: 14 impact quantities with attached marginal costs in the SPIQ-FS generic dataset

Cost Category	**Quantity**	**Unit**	**Marginal Cost**
GHG Emissions	CH4	Metric ton	CH4
GHG Emissions	N2O	Metric ton	N2O
GHG Emissions	CH4	Metric ton	CH4
Land use	Forest Habitat Loss	Ha	Forest Habitat Loss
Land use	Forest Habitat Return	Ha	Forest Habitat Return
Land use	Other Land Habitat Loss	Ha	Other Habitat Loss
Land use	Other Land Habitat Return	Ha	Other Habitat Return
Nitrogen Emissions	NOx	N-weight kg	NOx emissions to air
Nitrogen Emissions	NH3	N-weight kg	NH3 emissions to air
Nitrogen Emissions	Nr leached to groundwater	N-weight kg	NO3- leaching to groundwater
Nitrogen Emissions	Nr run-off to surface waters	N-weight kg	Nr run-off to surface water
Social indicators	Undernourished headcount	Ppl	Undernourishment (calories)
Social indicators	Headcount at poverty line $1.90 (2011 PPP)	Ppl	Poverty headcount at $1.90 a day (2011 PPP) (ppl)
Water use	Blue water used by crops	Cubic metre	Blue water

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Annex Z: Metadata

Metadata for the generic SPIQ-FS version 0 dataset.

Country Name: World Bank Country Names

Country Code: the country ISO 3166-1 alpha-3 code

M49: the UN numerical classification system of sovereign countries and territories (https://unstats.un.org/unsd/methodology/m49/)

scen: scenario, in this case constant marginal damages costs for status quo and counterfactual, including that future economic growth and development of both follows IPCC shared socioeconomic pathway SSP2.

year: year of the unit increase of an impact quantity

quantity: see Table 1

unit2, unit: the marginal cost item is in the units of unit2/unit

mean: the mean value of marginal damage cost with units of unit2/unit

mu: mean(log(samples)) – the mu parameter of a log normal fit of the samples (natural logarithm)

sigma: std(log(samples)) – the sigma parameter of a log normal fit of the samples (natural logarithm)

samples: samples of possible marginal damage costs values