WST008 – Europe's consumption footprint

Methodology

Different methodological approaches can be used to calculate consumption footprints. The two most widely used are the 'top-down' and the 'bottom-up' approaches. The former is based on translating EU consumption patterns into environmental impacts, using macro-level economic transactions data. The latter is based on life cycle assessment (LCA) and constructs the consumption footprint by focusing on a basket of representative products for a number of consumption areas. Section 3.5 of the Joint Research Centre (JRC) Technical Report by Sala et al. (2019) compares the results obtained by the two methodologies and reflects on strengths and weaknesses of each. For this indicator, the top-down approach is used, as this is more suitable for an indicator that aims to assess trends at a macro, EU level.

The methodology for this indicator can be split into two elements: the use of the Exiobase model and the application of the Environmental Footprint methodology.

The Exiobase model (description from the Exiobase website)

Exiobase 3 provides a time series of environmentally extended multi-regional input-output (EE MRIO) tables ranging from 1995 to a recent year for 44 countries (27 EU Member States plus 17 major economies) and five regions from the rest of the world. Exiobase 3 builds upon the previous versions of Exiobase by using rectangular supply-use tables (SUT) with 163 industries and 200 products being the main building blocks of the classification. The tables are provided in current, basic prices (million EUR).

Exiobase 3 is the culmination of the work of the FP7 Desire project and builds upon earlier work on Exiobase 2 in the FP7 CREEA project and on work on Exiobase 1 during the FP6 Exiopol project. These databases are available at the official Exiobase website.

A special issue of Journal of Industrial Ecology (Tukker et al., 2018) describes the build process and some use cases of Exiobase 3. This includes the article by Stadler et al. (2018) describing the compilation of Exiobase 3.

The original Exiobase 3 data series ends in 2011. Additional years are estimated based on a range of auxiliary data, but mainly trade and macro-economic data, taken from Eurostat, which go up to 2022 when including International Monetary Fund (IMF) expectations. Therefore, care must be taken in using the data.

The calculation methodology

The global distribution of pressures and effects related to the final consumption of households was calculated using an extended multi-regional input model based on a modified version of Exiobase v.3.8.2 (Stadler et al., 2021). For this purpose, environmentally extended product-by-product tables were used. The calculation started from the following identities:

$$x = A \cdot x + y \quad (1)$$

where x is the total output vector, A the matrix of direct input coefficients (or matrix of technological coefficients), and y is the final demand vector. Solving the model for output gives:

$$x = (I - A)^{-1} \cdot y = L \cdot y \qquad (2)$$

with identity matrix I, and matrix L the Leontief inverse also known as the multiplier matrix or matrix of direct and indirect output requirements per unit produced for final demand. The Leontief model implies the following assumptions: prices are fixed in the short term, input coefficients are constant regardless of output or final demand level changes and structure of the economy is taken to be constant, at least in the reported period.

The direct environmental effects of national production are the result of the sum of the direct effects associated with each unit produced in each industry:

$$e^T = \sum_1^n e_i = \sum_1^n e_i^{int} \cdot x_n = < e^{int} > \cdot x \qquad (3)$$

By multiplying the environmental pressure per output unit (measured in physical units per euro worth of output) with the total output of each industry (measured in Euro), defined by equation (2), an environmentally extended input-output model is created:

$$e^T = < e^{int} > \cdot x = < e^{int} > \cdot (I - A)^{-1} \cdot y \qquad (4)$$

where e^T is the vector of total environmental pressures associated with the corresponding amounts of the products groups finally used (vector y) and e^{int} the environmental pressure intensity vector. Each element of e^{int} represents the amount of the environmental pressure directly caused by the production of a product group. Each element of e^{int} in Exiobase is allocated to a sector-region combination, which allows to derive each of the 27 EU Member States' share in the total footprint.

To develop a time-series data set of environmental impacts, we applied several adjustments to the Exiobase data set:

- The **final demand vector of household consumption** (i.e. the final consumption expenditure of households) is disaggregated into consumption purposes based on the COICOP two-digit classification. The 2018 version (Department of Economic and Social Affairs, 2018) of the classification details 15 consumption domains of which the first 13 domains combine household expenditures. The last two domains represent the individual consumption expenditure of non-profit institutions serving households (NPISHs) and the individual consumption expenditures of general government. These are not household expenditures, but expenditures by NPISHs and governments directly supporting individual households in the domains of housing, health, recreation and culture, education, and social protection.

The allocation of the final demand vector of household consumption to the consumption domains is developed in Schepelmann et al. (2020).

- The **2020 Exiobase consumption data** are adjusted to reflect the 2020 household consumption trend data from Eurostat. This adjustment was required to include the impacts of the COVID-19 crisis in these results. The adjustments are based on the annual change in the period 2019-2020 per consumption domain available from the final consumption expenditure of household by consumption purpose data set [nama_10_co2_p3]. This change per consumption domain was applied to the EU-27 final demand data set in Exiobase to generate an adjusted 2020 final demand data set.
- The **material extraction data** are overwritten to match at country level with the United Nations Environment Programme Global Material Flows Database (UNEP, 2020). The extensions on domestic extraction used in Exiobase are modified to match with the total domestic extraction per material flow type, per year and per country from the UNEP database. The inner country sectoral distribution available from Exiobase remains unchanged.

The end years of the extension tables vary. This means that the extension tables are based on real data up to a certain year and then the extension coefficients are kept constant. This also means that the footprint calculations capture only changes in environmental impacts due to changes in output volumes. Changes in environmental efficiency per unit of output are not captured. The end years of the extension tables are 2015 for energy, 2019 for all greenhouse gases (non-fuel, non-CO_2 are nowcasted from 2018), 2013 for material use (but this is overwritten using the UNEP database) and 2011 for most others, land and water.

Application of the Environmental Footprint methodology

Applying the methodology as described above gives individual results for each environmental extension available from the Exiobase data set.

In a next step, these extensions are translated into environmental impact categories according to the Environmental Footprint method v1.02. Translating the 1,113 available (not all of them are eventually used) extension lines into the 16 impact categories of the Environmental Footprint method requires a conversion through characterisation factors, available through the Environmental Footprint method.

An important point to note here is that the Environmental Footprint method defines characterisation factors for more emissions and resources extracted than available in Exiobase. For some environmental impacts, such as climate change, the coverage of Exiobase is quite complete. For other impacts, however, such as toxicity, Exiobase includes only a very limited selection of emissions. No information, and thus no extension lines, is available in Exiobase to estimate the impact categories ozone depletion and ionising radiation.

The next step normalises and weighs the different environmental impact categories to calculate the environmental footprint (expressed in points, Pt) as one aggregated score. The normalisation factors and weighting factors are copied from the Environmental Footprint method. The normalisation and weighting allow all environmental impacts to be expressed as a single score. The following table shows the normalisation and weighting factors.

	kg CO2 eq	kg CFC11 eq	kBq U-235 eq	kg NMVOC eq	disease inc.	CTUh	CTUh	mol H+ eq	kg P eq	kg N eq	mol N eq	CTUe	Pt	m3 depriv.	MJ	kg Sb eq
	Climate change	ozone depletion	Ionising radiation	photochemical ozone formation	Particulate Matter	Human toxicity, non-cancer	Human toxicity, cancer	Acidification	Eutrophication, freshwater	Eutrophication, marine	Eutrophication, terrestrial	Ecotoxicity, freshwater	Land use	Water use	Resource use, fossils	Resource use, minerals and
Normalization factor	0.0001235	18.64	0.000237	0.02463	1680	4354	59173	0.018	0.6223	0.05116	0.005658	2.343E-05	1.22E-06	8.719E-05	1.538E-05	15.71
Weighting factor (Pt)	0.2106	0.0631	0.0501	0.0478	0.0896	0.0184	0.0213	0.062	0.028	0.0296	0.0371	0.0192	0.0794	0.0851	0.0832	0.0755