SUPPLEMENTARY INFORMATION 2

Diverse consumption patterns in countries nearing social and climate goals challenge their use as role models

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1. Mathematical modelling with GMRIO

1.1. National per capita spending and carbon footprints

The national consumption-based carbon footprints (CF) rely on global multi-regional input-output (GMRIO) tables, which track monetary flows between countries and industry sectors, allowing a country's emissions to include those embodied in imported goods while excluding emissions from exports. Among publicly available databases with harmonized country- and sector-level resolution, the Global Resource Input-Output Assessment (GLORIA) database was selected (Industrial Ecology Virtual Laboratory, 2021). GLORIA provides detailed coverage across 164 countries/regions, 120 economic sectors and is regularly updated, making it a relevant choice for this analysis.

The mathematical model builds on the theory of input-output analysis described by Miller & Blair (2009). To apply it, several matrices and vectors are derived from GLORIA's Multi Regional Supply Use Tables (MR-SUT) (Industrial Ecology Virtual Laboratory, 2021; United Nations, 2018). GLORIA Multi-region input-output (MRIO) database provides tables for supply-use transactions in a transaction matrix ***T***. This matrix maps all the inputs (as rows) necessary for each industry output (columns). The ***Y*** matrix stands for the sales of industry to economic agents such as households, the government and the capital sector. ***T*** and ***Y*** allow calculating the total required inputs to fulfil the world's demand ***x***, following equation (1). For simplicity the ***Y*** final demand matrix is transformed as a single final demand vector ***y***.

$$x = \mathrm{T} \cdot e + y \tag{1}$$

The input coefficient matrix ***A***, representing the required input per unit of output can then be obtained with equation (2), where $\hat{x} = diag(x)$. The Leontief Inverse ***L***, which is a geometric series of ***A***, enables the backtrack of monetary flows of the supply chain of each of the final output products (equation 3). Multiplying the Leontief matrix ***L*** by ***y*** enables us to get the full picture of which flows of products of the global market economy satisfy the final demand of each of the 163 countries.

$$\mathrm{A} = \mathrm{T} \cdot \hat{x}^{-1} \tag{2}$$

$$\mathrm{L} = (\mathrm{I} - \mathrm{A})^{-1} \tag{3}$$

Each product flow is linked to a quantity of greenhouse gases emissions (comprising resource extraction, and emissions occurring at various points of the industries' supply chain), represented in the characterization vector $\boldsymbol{s}$. Finally, direct emissions coming from the consumption of those products in all countries are represented in the vector $\boldsymbol{f_c}$. The total carbon footprint $\boldsymbol{cf_c}$ coming from the consumption of country $\boldsymbol{c}$, having a demand $\boldsymbol{y_c}$ and direct emissions $\boldsymbol{f_c}$ can be calculated using equation (4).

$$\forall c \in [\![1; C]\!],\ cf_c = s \cdot L \cdot y_c + \sum_{i \in [\![1; P \times C]\!]} (f_c)_i \tag{4}$$

Where $\boldsymbol{P}$ is the number of products, and $\boldsymbol{C}$ the number of countries covered by the GLORIA GMRIO database.

As it was unclear if the GHG emissions in GLORIA environmental extensions were characterized using the fifth or sixth Assessment Report (AR5 or AR6) of the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC), we have directly applied the selected characterization factors. First, we use GLORIA environmental extensions, which link economic activities to their different greenhouse gas emissions, as emissions ca be found expressed in Kg of the substance considered. Then those emissions have been characterized into CO_2 equivalent (CO_2e) units, using for each greenhouse gas considered, its Global Warming Potential over 100 years (GWP100). Those GWP100 characterization factors have been retrieved from AR6 (IPCC, 2023). The list of greenhouse gas emissions and the characterization factors are listed in Table S1.

Table S1 – Characterization factors for Greenhouse gases based on 100-year Global Warming Potential from the sixth Assessment Report (AR6) of the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC, 2023). Numbers are expressed in CO_2 equivalent (CO_2e) units.

Nr	Chemical Substance	Gas	GWP-100
1	C4F8	F-Gas	13900
2	C2F6	F-Gas	12400
3	C3F8	F-Gas	9290
4	C4F10	F-Gas	10000
5	C5F12	F-Gas	9220
6	C6F14	F-Gas	8620
7	C7F16	F-Gas	8410
8	CF4	F-Gas	7380
9	HCFC_141B	F-Gas	860
10	HCFC_142B	F-Gas	2300
11	HFC_23	F-Gas	14600
12	HFC_32	F-Gas	771
13	HFC_41	F-Gas	135
14	HFC_43_10_MME	F-Gas	1600
15	HFC_125	F-Gas	3740
16	HFC_134A	F-Gas	1530
17	HFC_143A	F-Gas	5810
18	HFC_152A	F-Gas	164
19	HFC_227EA	F-Gas	3600
20	HFC_236FA	F-Gas	8690
21	HFC_245FA	F-Gas	962
22	HFC_365MFC	F-Gas	914
23	NF3	F-Gas	17400
24	SF6	F-Gas	24300
25	CO2 excluding short cycle organic C	CO_2	1
26	CO2 short cycle organic C	CO_2	1
27	N2O	N_2O	273
28	CH4	CH_4	27.9

1.2. Spendings and emissions patterns

Each of the countries included in this study, i.e., that had a CF and a NSI available (***C***=139) was screened for their spendings and emissions patterns. The GLORIA database contains (***P***=120) product categories. For the population of each country c, the spendings $\mathbf{M_{c,p}}$ associated with the consumption of products from category ***p*** is calculated following equation 6 by summing the spending on these products across all countries.

$$\forall(c,p) \in [\![1;C]\!] \times [\![1;P]\!],\ M_{\mathrm{c,p}} = \sum_{i\in[\![1;C]\!]}(y_c)_{p+(i-1)p} \quad (6)$$

Similarly, for emissions, the carbon footprint associated with the consumption of all products of category ***p*** in a country ***c*** is calculated as shown in equation 7:

$$\forall(c,p) \in [\![1;C]\!] \times [\![1;P]\!],\ \mathrm{CF_{c,p}} = \sum_{i\in[\![1;C]\!]}(\hat{s} \cdot L \cdot y_c)_{p+(i-1)p} \quad (7)$$

Where $\hat{\boldsymbol{s}}$ is a diagonal matrix, defined by equation 8:

$$\forall \mathrm{i} \in [\![1;C]\!] \times [\![1;P]\!], \hat{s}_{i,i} = s_i \quad (8)$$

For carbon footprints, direct emissions from country c (denoted as f_c in equation 4), primarily come from household activities that release greenhouse gases through the combustion of fossil fuels. These emissions can be further allocated to the "mobility" category (e.g., gasoline and diesel consumption) and the "housing" category (e.g., fuel used for home heating). To make these allocations, we used the EXIOBASE hybrid GMRIO database (Merciai & Schmidt, 2018), which provides fossil fuel demand in physical rather than financial units. By multiplying this data by an emission factor, it is possible to estimate the share of direct emissions attributed to each category (mobility or housing). The tables used to perform such an allocation are also detailed in Supplementary Information 1.

1.3. Classification into 5 consumption categories

As the GLORIA database classifies products into 120 categories, it allows for calculating the average contribution of each category to total spending or the carbon footprint for every country. To facilitate interpretation, those 120 categories were further aggregated following the approach of Ivanova & Wood (2020), who used another GMRIO database, EXIOBASE, to allocate 200 product categories into seven consumption categories: Food, Housing, Clothing, Manufactured products, Land travel, Air travel, and Services. We further consolidated land and air travel into a "Mobility" category and Clothing and Manufactured products into a "Consumables" category, resulting in five categories. Details of the allocation of product categories into these five groups can be found in SI1.

2. Short literature review on social performance indicators of countries

The existing literature has used a range of different indicators to quantify the social performance of countries, encompassing various aspects of welfare, social well-being, and overall human development. One of the most widely recognized measures is the Human Development Index (HDI), developed by the United Nations Development Programme (UNDP, 2024). It assesses countries based on life expectancy, education (mean and expected years of schooling), and gross national income (GNI) per capita, adjusted for purchasing power parity (PPP). Heide et al. (2023) utilized HDI as a proxy for assessing a country's social performance. However, despite capturing fundamental aspects of human development, HDI has been subject to significant criticism for its limited scope, particularly its omission of broader social and well-being dimensions (Ranis et al., 2006; Ravallion, 2012; Sagar & Najam, 1998). To provide a more comprehensive assessment, the OECD's Better Life Index, created in 2011, considers 11 dimensions, additionally including jobs, housing, social connections, equality, civic engagement, safety and environmental quality, and thereby offering a multidimensional assessment of societal well-being (OECD, 2025).

O'Neill et al. (2018) build on the Safe and Just space framework of Raworth (2017) and the Sustainable Development Goals (SDGs; United Nations, 2015), to both make a set of 11 similar social indicators, adding life satisfaction "to provide both subjective and objective measures of well-being," and social support due to "its importance for well-being". They however exclude indicators such as gender equality and safety "on the grounds that these are cross-cutting issues that should be incorporated into the other social measures". In their work on the development of composite indicators to evaluate the environmental and social performance of countries, Gucciardi & Luzzati (2024) use a very similar set of social dimensions. Finally, Desmoitier et al. (2023) conduct a literature review and propose the most complete set of indicators, representing 15 social foundation dimensions, many of which align with the SDGs. A summary of all the dimensions used by the aforementioned frameworks and studies is made in Table S2.

We selected our indicators based on the approach of Desmoitier et al., which was the most complete. To look at how countries can achieve climate sustainability while keeping basic welfare, we left out social indicators that are only lightly or not at all connected to greenhouse gas emissions. This follows the approach of O'Neill et al. (2018), who noted that a country's results on some social goals have little to do with its carbon footprint. Because of this, we did not include measures for employment, safety, or gender equality, leaving a focused set of 12 indicators.

Table S2 – Social dimensions included in the indicators of the frameworks reviewed in this study. "X" indicated that the dimension is not covered by the framework.

Social Dimension	**HDI (UNDP, 2024)**	**Better Life Index (OECD, 2025)**	**Doughnut framework (Raworth, 2017)**	**O'Neill et al. (2018)**	**Gucciardi & Luzzati (2024)**	**Desmoitier et al. (2023)**	**This study**
Health / Life expectancy	Life Expectancy	Health	Health care	Healthy life expectancy	Life Expectancy	Health	**Life expectancy**
Education / Knowledge	Years of schooling	Knowledge and skills	Education	Education	Education	Education	**Education**
Income	Income	Income and wealth	Income	Income	Income poverty	Income	**Income**
Jobs / Employment quality	X	Work and job quality & Work-life balance	Jobs	Employment	Employment	Work	X
Housing / Shelter	X	Housing	X	X	X	Housing	**Housing**
Social support / Community	X	Social connections	X	Social support	Social support	Networks	**Social support**
Social equality / Equity	X	Income and wealth	Social equity	Equality	Equality	Social equity	**Equality**
Gender equality	X	X	Gender equality	X	X	Gender equality	X
Life Satisfaction / Well-being	X	Subjective well-being	X	Life satisfaction	Life satisfaction	Life satisfaction	**Life satisfaction**
Nutrition / Food security	X	X	Food security	Nutrition	Nutrition	Food	**Nutrition**
Water / Sanitation	X	X	Water and sanitation	Sanitation	Sanitation	Water & Sanitation	**Water access & Sanitation**
Energy access	X	X	Energy	Access to energy	Access to energy	Energy	**Energy access**
Political voice / Democracy / Rights	X	Civic Engagement	Voice	Democratic quality	Democratic quality	Democratic rights	**Democracy**
Safety / Security	X	Safety	Resilience	X	X	Safety and justice	X
Environmental quality	X	Environment al quality	X	X	X	X	X

3. Additional figures and tables

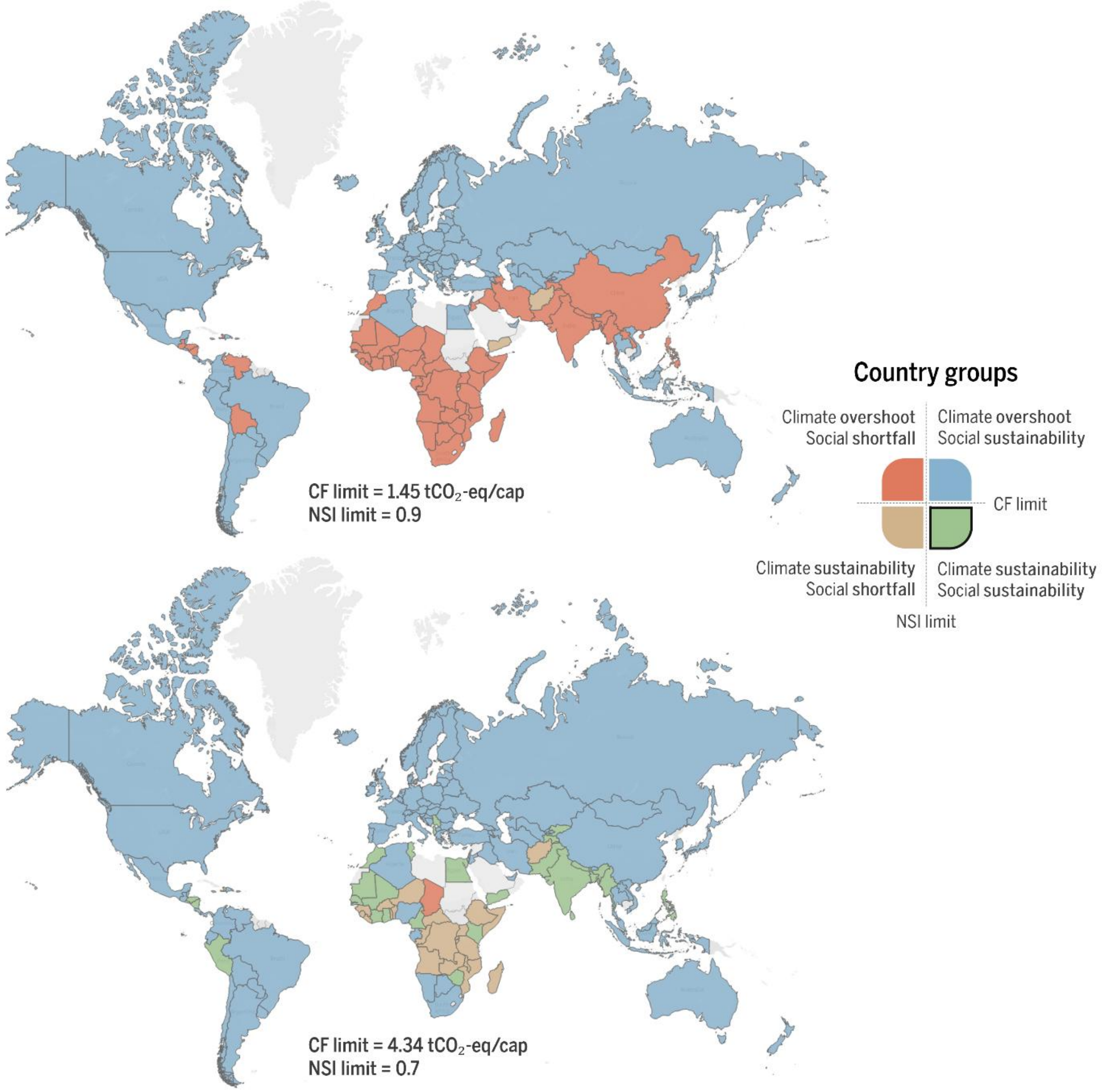

Figure S1 – Carbon footprint (CF) of the 139 countries selected, plotted against their Needs Satisfaction Index (NSI) in 2019. A color coding represents the categories in which the countries fall, depending on their position with the two defined absolute thresholds for CF and NSI (CF limit and NSI limit), for the two extreme cases of the sensitivity analysis conducted on the model area, which includes the country both sustainable from a climate and social perspective (see Fig. 4). Regions displayed in light grey indicate missing data, either for CF or for NSI. Data pertaining to this graph is available in SI1.

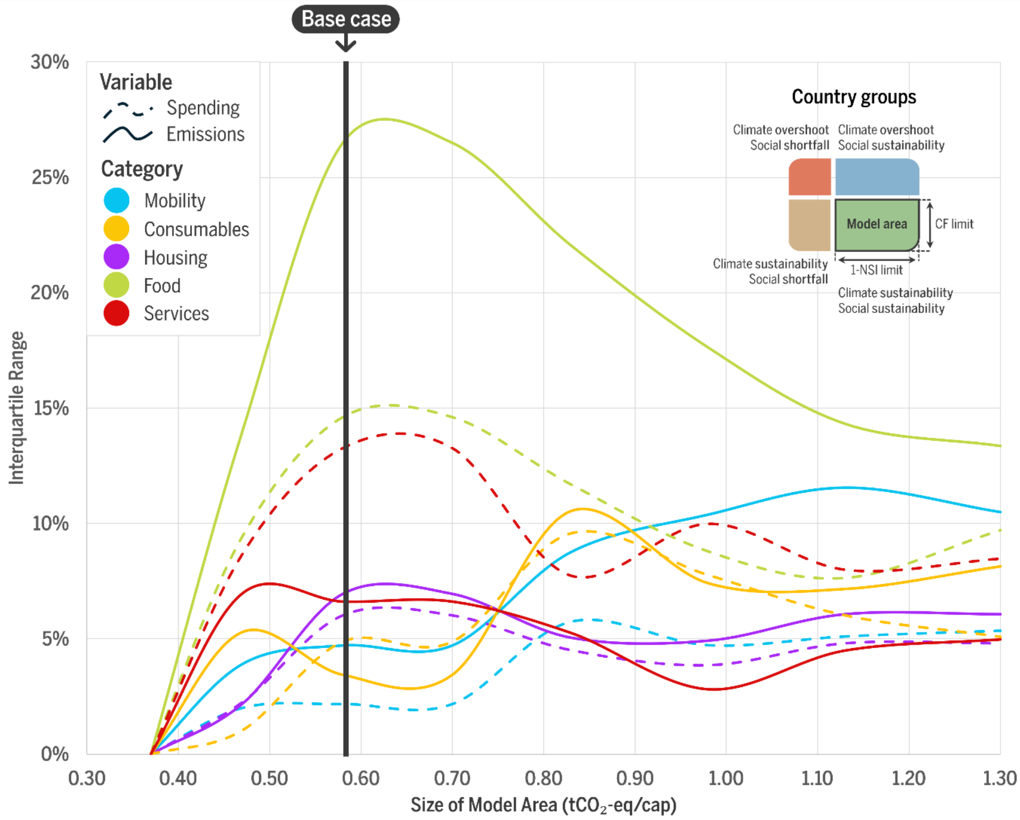

*Figure S2 – Evolution of the interquartile range of the emission and spending contribution to each consumption categories, according to the size of the "model area", expressed as (1-NSI limit)*CF limit, NSI limit and CF limit being the thresholds above (resp. under) which a country is considered sustainable in social (resp. climate) terms, on the categorization of countries among the different country groups. Data pertaining to this Figure is available in SI1.*

Table S3 – Results of the one-way ANOVA, testing whether the mean share of each sector differs significantly between the model group and the non-model group, for different sizes of the model area (including more or less countries in the model group). "No" indicates no statistically significant difference between the two groups. When they are statistically different, the difference of contribution to total emissions (or spendings) of each consumption category between the model group and the non-model group is written. For example, when 20 countries are included in the model area (the model area being 96% larger than the base case), the emissions coming from food in model countries is on average 5 percentage points higher than in non-model countries.

	Number of countries included in model area	1	2	**4**	4	9	15	20	28
	Size of model area compared to base case	**-36%**	**-19%**	**Base case**	**21%**	**44%**	**69%**	**96%**	**125%**
Emissions	Food	No	No	**No**	No	No	7%	5%	6%
	Mobility	No	No	**No**	No	No	No	No	No
	Consumables	No	No	**No**	No	No	No	No	No
	Housing	No	No	**No**	No	No	No	No	No
	Services	14%	7%	**No**	No	No	No	No	No
Spendings	Food	No	No	**No**	No	6%	6%	5%	6%
	Mobility	No	No	**No**	No	No	No	No	No
	Consumables	No	No	**No**	No	No	No	No	No
	Housing	No	No	**No**	No	No	No	No	No
	Services	No	No	**No**	No	No	No	No	-4%

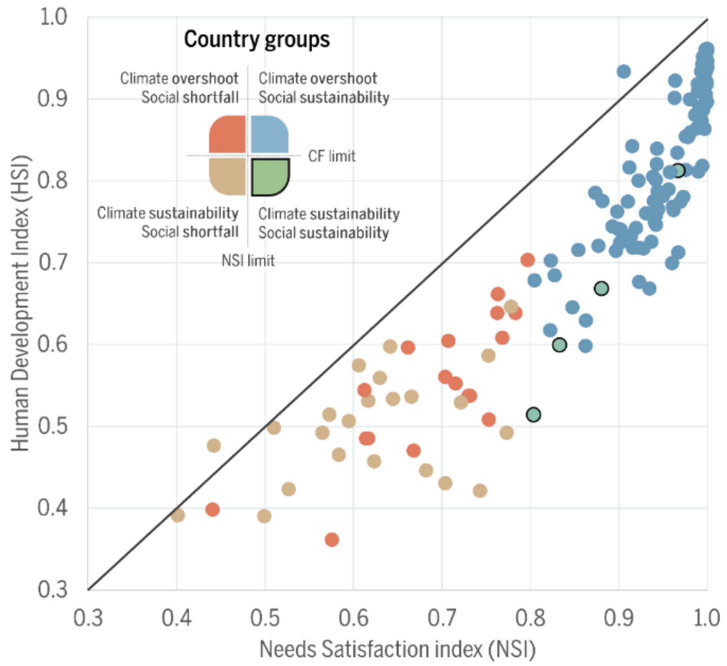

Figure S3 – Human Development Index plotted against the Needs Satisfaction Index. A 1:1 identity line is plotted. Data pertaining to this graph is available in SI1.

4. References

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