

Polarizing and equalizing trends in international trade and Sustainable Development Goals

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Contents

1. Supplementary Introduction.....	2
2. Supplementary Methods	5
2.1. Regional coverage.....	5
2.2. Organisation of variants in the main text figures: <i>p</i> = reporting region.....	6
2.3. Detailed overview of constructing the environmental and social proxies.	6
3. Supplementary Results	10
3.1. Energy	10
3.2. GHG emissions and Air Pollution	11
3.3. Water stress	13
3.4. Materials	14
3.5. Land and Biodiversity.....	15
3.6. Nitrogen	17
3.7. Women’s Participation and Labour Skills	17
3.8. Poverty	20
3.9. Occupational Accidents.....	21
4. Uncertainty analysis.....	23
5. Supplementary Discussion	28
References	30

1. Supplementary Introduction

With six years left to achieve the Sustainable Development Goals (SDGs), accurately measuring progress is essential for countries to understand what gaps and opportunities remain^{1,2}. The SDGs are part of the 2030 Agenda for Sustainable Development established by the United Nations (UN) in 2015^{3,4}. As part of the seventeen goals, 169 targets and 231 indicators exist^{3,4}. The targets provide guidance on *how to progress* towards the goals, while the indicators provide detail on *how to measure* of the progress toward goals and targets^{1,4}. The effectiveness of the indicators often comes under scrutiny as "indicators that are well measured, accurate, timely, and relevant for every part of the world are certainly not at hand right now, and it is going to take a number of years before they will be" (p. 1458.)¹. The UN Global SDG Report includes a similar warning that "the lack, in many parts of the world, of adequate data, to assess national trends and to inform and monitor the implementation of development policies" can obscure the reality of progress (p. 62.)⁵.

Numerous tracking initiatives exist to measure national performance against the SDGs. The United Nations leads the collection and aggregation of data on national performance for monitoring the SDGs. Their annual Sustainable Development Goals Reports are the official reports on global progress based on the data from the UN Statistics Division global SDG indicator database^{1,6}. The 2021 UN Sustainable Development Goals Progress Chart presents a high-level overview of progress, noting that data gaps remain due to statistical offices' shutdowns during the COVID-19 pandemic⁷. Other organisations leverage data collected and reported by the UN to monitor progress. The SDG Tracker, a resource by the Global Change Data Lab, uses official UN-reported data on the SDGs to present national progress². The Organisation for Economic Co-operation and Development (OECD) studies how its 35 member countries stand in reaching the SDGs^{1,8}. Beyond global reports by the UN and other organisations, many governments develop their own reports outlining national or regional achievements and progress^{9,10}.

The global attention on the effects of supply chain disruptions caused by COVID-19, conflicts in Russia and Ukraine, and extreme weather events have illuminated how progress toward the SDGs can be indirectly hindered¹¹. However, the quantification of supply chain impacts is often underreported. The 2022 SDG Report by the UN Secretary-General does not mention the terms 'indirect/ly' and 'embodied' and only two mentions of the term 'footprint', which often encompasses methods that account for hidden impacts¹¹. Statements such as "33 countries reported direct economic losses in 2020 due to other disasters in the amount of \$16.55 billion" (p. 4.)¹¹ exclude mention or measurement of the interconnected nature of the effects of these hazards on other economies. Similarly, the UN's official and extended Report on SDG progress makes no mention of the terms 'embodied' and one mention of the term 'footprint'. However, it mentions the term 'indirectly' three times, albeit not in the context of how indirect impacts cascade globally, hindering SDG progress⁵. This is despite the knowledge that SDG progress can be influenced by many intersecting and compounding factors, including power distributions across global value chains¹²⁻¹⁴, social or political polarization¹⁵ (the division of society into groups based on race, religion, and/or politics¹⁶), geopolitical conflict¹⁷, disasters¹⁵, and international trade. The lack of representation of indirect impacts in global progress reports by the UN contrasts the academic literature, where scholars assert the significance of cascading spillover or transboundary impacts^{18,19}.

Transboundary impacts are defined "as the impacts of one country beyond their borders on (i) other countries and (ii) global common goods. These impacts can be both bilateral (from one country to another) and multilateral (from one country to many others)" (p. 9.)²⁰. Spillover impacts are also addressed using terms such as "outsourcing" and "leakage". Outsourcing has been quantified at a global

level for greenhouse gas (GHG) emissions²¹⁻²³, air pollutants²⁴, energy use²⁵, material use²⁶, land and water^{27,28}, labour (master-servant) relationships²⁹, inequality³⁰, child labour³¹, bad labor³², occupational health³³ and modern slavery³⁴. Outsourcing by individual regions, such as the EU, have also been analysed³⁵. Researchers employ diverse methods to capture and quantify the effects of transboundary or spillover impacts³⁶.

One methodology for assessing spillover impacts is multi-region input-output (MRIO) analysis. MRIO analysis, based on economic input-output tables produced by national statistical agencies, captures the flow of monetary goods and, thus, the interaction of sectors and regions within economies. Application of MRIO analysis is extended to a diverse range of problems, from quantifying the footprints of various pollutants, materials or products³⁷⁻⁴⁰ to the economic, social, and environmental impacts of hazards in supply chains and the embodied impacts of particular products occurring in imports and exports⁴¹⁻⁴⁵. The extension of MRIO analysis to such problems is made possible by satellite accounts, which capture physical, non-monetary data. MRIO analysis is valuable concerning the SDGs because it has timeseries tables, which means that we can track progress in terms of trends in imports and exports over time; and how this pans out at a global level. Beyond academia, insights from MRIO databases now widely feature in reports produced by leading international bodies such as the Intergovernmental Panel on Climate Change (IPCC)⁴⁶, the UN SDSN⁴⁷, the International Monetary Fund⁴⁸, the World Bank⁴⁹, the International Resource Panel⁵⁰ and the OECD⁵¹. The Hotspot Analysis Tool for Sustainable Consumption and Production (SCP-HAT)⁵², commissioned by the United Nations Environment Programme (UNEP), which applies the GLORIA database⁵³, can be used for the development of policy instruments aimed at supporting the shift to sustainable production and consumption, as called for under target 12.1, and the development and update of Nationally Determined Contributions (NDC) to greenhouse gas emissions reductions, as called for under the Paris Agreement.

At the mid-point of SDG progress, the 2023 Sustainable Development Goals Report and SDG Trackers illustrate a bleak picture of SDG progress^{15,54,55}, exacerbated by the lingering effects of COVID-19 crisis, the ongoing war in Ukraine, persistent disasters, and internal conflict¹⁵. According to the 2023 Sustainable Development Goals Report, only 15% of the SDGs are on track, 48% are moderately or severely off track, and 38% have stagnated or regressed¹⁵. Nationally, the effects of global and national crises that impact the SDGs vary significantly. For example, the COVID-19 pandemic caused the greatest SDG setbacks in South America, the Caribbean, South Asia, the Middle East and North Africa (MENA), and Sub-Saharan Africa⁵⁴.

The SDG Report and various SDG trackers present SDG progress from a territorial perspective on the progress occurring within a region. Even reports such as the European Union's report on SDG progress⁵⁶ summarise national progress within the region. Currently, only SDG Spillover reports⁵⁷, produced by the United Nations consider SDG progress from a consumption-based perspective, i.e., how the consumption of goods and services in one region may impact another through supply chains. The consumption perspective is important as it demonstrates how countries where overall SDG progress is on track contribute to negative consequences for other regions⁵⁷.

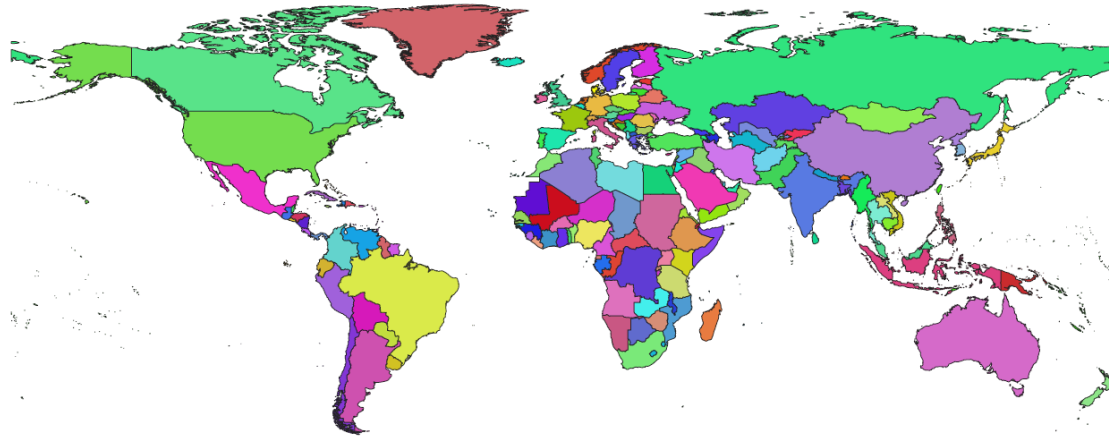
Recently, scholars have demonstrated the significance and use of MRIO analysis in measuring SDG progress^{40,42,58,59}. Primarily, in the context of the SDGs and the quantification of indirect or supply chain impacts, research is based around SDG12 (Responsible Production and Consumption) and SDG8 (Decent Work and Economic Growth)^{18,60}. Lenzen, et al. ⁶⁰, using MRIO analysis, created a collaborative platform to enable countries to “produce, update and report detailed global material footprint accounts and monitor progress towards Sustainable Development Goals 8.4 and 12.2” (p.

157.). Wiedmann and Allen ⁴⁰ review the literature on cities and sustainable development. They find that "deriving city-scale input-output tables and associated environmental and social satellite accounts is a relatively new, but yet to be improved, field of research that promises to capture better urban idiosyncrasies and supply chains of regional to global reach" (p. 7.)⁴⁰. Malik, et al. ⁴² used MRIO analysis to trace the social impacts, specifically related to occupational injuries represented in SDG 8 (Decent Work and Economic Growth), generated by the EU's imports and exports (SDG12). Xiao, et al. ⁵⁸ used input-output analysis to calculate a consumer social risk footprint (SF) of nations' imports (SDG12), measuring indicators under SDG5, 7, 3, 16, and 6. However, studies capturing the spillover effects and linkages between the SDGs and trade still need development.

Here, we offer a systematic quantitative assessment of SDGs in terms of outsourcing trends at a global level from a time-series perspective. We quantify impacts in terms of *polarising* and *equalising* trends – concepts introduced in this study in the context of international trade to track trends of individual countries over time toward deterioration of existing disparities in nations (- *polarisation*) or mitigation and reduction of disparities (- *equalisation*). The concept of polarisation has its beginnings in economics literature^{61,62}. Polarisation, concerned with a divergence between homogenous groups and their distribution^{61,63}, is closely related to inequality⁶⁴. Political polarisation, referred to as the gap in political attitudes and identities among the public⁶⁵, increases as income inequality widens⁶⁵. The bi-directional correlation between income inequality and political polarisation is echoed by other researchers⁶⁶. Inequality is a prevalent issue for policymakers as it affects poverty and social outcomes, essential to promoting sustainable development⁶⁴. Just like inequality, polarisation, particularly political polarisation, is problematic for policymakers as well given its relationship to inequality and effect on conflict⁶⁶. Equalisation is applied to a much wider tranche of literature than polarisation, which is mainly confined to politics. For example, equalisation has been seen across literature concerning greater innovation and emissions reduction⁶⁷, the transfer of fiscal resources across jurisdictions⁶⁸ and the equalisation of public services to promote social adhesion⁶⁹. An equal-opportunity approach was developed and applied to a set of countries to overcome the treatment of inequality between *countries*, which is typically ignored by economic measures such as gross domestic product (GDP) and the Human Development Index (HDI)⁷⁰. However, research linking the polarisation-equalisation concepts to trade does not exist. Globalisation has profoundly affected the state of inequality and polarisation⁶³. Understanding how the two interact across boundaries is critical. MRIO analysis can fill this need.

2. Supplementary Methods

2.1. Regional coverage



Afghanistan	Burkina Faso	Botswana	Cuba	Spain	Greece	Iceland	Laos	Macedonia	Nicaragua	Poland	Sierra Leone	Tajikistan	Yemen Arab Republic/ Yemen (1989/1990)
Angola	Bangladesh	Central African Republic	Cyprus	Estonia	Guatemala	Israel	Lebanon	Mali	Netherlands	North Korea	El Salvador	Turkmenistan	South Africa
Albania	Bulgaria	Canada	CSSR/Czech Republic (1992/1993)	Ethiopia/DR Ethiopia (1992/1993)	Honduras	Italy	Liberia	Malta	Norway	Portugal	Somalia	Tunisia	Zambia
United Arab Emirates	Bahrain	Switzerland	Germany	Finland	Hong Kong	Jamaica	Libya	Myanmar	Nepal	Paraguay	Yugoslavia/Serbia (1991/1992)	Turkey	Zimbabwe
Argentina	Bahamas	Chile	Djibouti	France	Croatia	Jordan	Sri Lanka	Mongolia	New Zealand	Qatar	Sudan/North Sudan (2010/2011)	Tanzania	Rest of Americas
Armenia	Bosnia and Herzegovina	China	DR Yemen (Aden)	Gabon	Haiti	Japan	Lithuania	Mozambique	Oman	Romania	Slovakia	Uganda	Rest of Europe
Australia	Belarus	Cote d'Ivoire	Denmark	United Kingdom	Hungary	Kazakhstan	Luxembourg	Mauritania	Pakistan	USSR/Russian Federation (1990/1991)	Slovenia	Ukraine	Rest of Africa
Austria	Belize	Cameroon	Dominican Republic	Georgia	Indonesia	Kenya	Latvia	Malawi	Palestine	Rwanda	Sweden	Uruguay	Rest of Asia-Pacific
Azerbaijan	Bolivia	DR Congo	Algeria	Ghana	India	Kyrgyzstan	Morocco	Malaysia	Panama	Saudi Arabia	Syria	United States of America	
Burundi	Brazil	Rep Congo	Ecuador	Guinea	Ireland	Cambodia	Moldova	Namibia	Peru	South Sudan	Chad	Uzbekistan	
Brunei	Brunei	Colombia	Egypt	Gambia	Iran	South Korea	Madagascar	Niger	Philippines	Senegal	Togo	Venezuela	
Belgium	Darussalam												
Benin	Bhutan	Costa Rica	Eritrea	Equatorial Guinea	Iraq	Kuwait	Mexico	Nigeria	Papua New Guinea	Singapore	Thailand	Viet Nam	

Fig S1: Connecting SDGs to quantitative proxies. Source: Generated by authors.

2.2. Organisation of variants in the main text figures: p = reporting region.

Table S1: Organisation of variants in the main text figures

	by producing industry i	by origin – destination $p \leftrightarrow s, s \leftrightarrow p$	by selling region $p \leftrightarrow r, r \leftrightarrow p$	by consumed product j
Producers' and trade perspective	Domestic production of factor q by industry i in region p , over time t $F_{i,t}^{q,p} = \sum_j^{rs} F_{ij,t}^{q,p,rs}$ $= Q_{i,t}^{q,p}$	Destination of domestic production of factor q in region p , by destination s , over time t $F_{\cdot,t}^{q,p,s} = \sum_{ij}^r F_{ij,t}^{q,p,rs}$	Trade of production of factor q by region p , to destination s , over time t $F_{\cdot,t}^{q,p,s} = \sum_{ij}^r F_{ij,t}^{q,r,ps}$	Trade of production of factor q by region p , of consumed product j , over time t $F_{\cdot,t}^{q,p,j} = \sum_i^{rs} F_{ij,t}^{q,r,ps}$
Consumers' perspective	Origin of domestic footprint of factor q in region p , by producing industry i , over time t $F_{i,t}^{q,\cdot,p} = \sum_j^{rs} F_{ij,t}^{q,srp}$	Origin of domestic footprint of factor q in region p , by origin s , over time t $F_{\cdot,t}^{q,s,p} = \sum_{ij}^r F_{ij,t}^{q,srp}$	Composition of domestic footprint of factor q in region p , by seller r , over time t $F_{\cdot,t}^{q,\cdot,p} = \sum_{ij}^s F_{ij,t}^{q,srp}$	Composition of domestic footprint of factor q in region p , by consumed product j , over time t $F_{\cdot,t}^{q,\cdot,p} = \sum_i^{rs} F_{ij,t}^{q,srp}$

2.3. Detailed overview of constructing the environmental and social proxies.

In the following we describe the 12 selected environmental and social proxies linked to the SDGs (Fig S2). For ease of interpretation, we define the proxies such that they are considered bad/detrimental for the accomplishment of the SDGs. The proxies are:

- 1) *GHG emissions*: We source data from the EDGAR v.5.0 database^{71,72}, maintained by the European Commission Joint Research Centre (JRC) and the Netherlands Environmental Assessment Agency (PBL), to characterise region- and sector-specific anthropogenic GHG emissions. We consider emissions for the gases: carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Construction of this proxy was done through the implementation of a so-called “satellite account” linked with the MRIO database, which required the use of total sectoral output as additional data for allocating emissions to the MRIO database (see *SI* of Lenzen *et al.* 2012⁷³ for details). Emissions from road transportation in EDGAR are disaggregated into industries and households in the MRIO database by following region-specific private car shares⁷⁴. This proxy is presented in the units of tonnes. This proxy has been linked to SDG 13 (Climate Action) in consideration that CO₂, CH₄, and N₂O are main GHGs. As such, this proxy directly coincides with the indicator 13.2.2 of the UN global indicator framework² which measures progress towards target 13.2 of SDG 13.
- 2) *Air pollutants*: We cover three main air pollutants: Sulphur dioxide (SO₂), particulate matter of particles smaller than 2.5 µm in diameter (PM2.5), and nitrogen oxides (NOx). This proxy is developed by applying characterisation factors to emissions' data from EDGAR v.5.0 database^{71,72}, expressed in Disability-Adjusted Life Years. This proxy is presented in the units of tonnes and has been linked to SDG 11 (Sustainable Cities and Communities), in view of air quality being a key dimension of SDG 11's target 11.6. Specifically, one of the UN proposed indicators for that target (indicator 11.6.2) focuses on PM2.5.
- 3) *Land*: We cover six land use classes: Annual crops, Permanent crops, Pasture, Extensive forestry, Intensive forestry, and Urban, based on data from the Food and Agriculture Organization Corporate Statistical (FAOSTAT) Land Use domain. We map these land use classes to GLORIA MRIO table following the approach outlined in Annex VIII of the Sustainable Consumption and Production Hotspots Analysis Tool (SCP-HAT) - technical documentation⁷⁵. This proxy is presented in the units of hectares. This proxy has been linked to

SDG 2 (Zero Hunger), considering that its target 2.4 argues for the need to ensure sustainable food production systems that increase productivity. Given that humanity has surpassed a safe level of land-system change (as described in the Planetary Boundaries framework⁷⁶), we assume that growth in crop area is an unsustainable trend, therefore connecting it with SDG 2. Of course, this premise and proxy are incomplete, and future research should consider the impacts of different types of agricultural practices.

- 4) *Biodiversity*: This proxy builds on the land use proxy by applying characterisation factors for global species loss on land use categories to yield a measure of Potentially Disappeared Fraction of species (*i.e.*, temporary loss of biodiversity from land occupation, refer to land use-specific UNEP global guidance for Life Cycle Impact Assessment indicators⁷⁷ for characterisation of biodiversity impacts from land use). This proxy is presented in the units of potentially disappeared fraction of species. This proxy has been linked to SDG 15 (Life on Land), given that its target 15.5 calls for reducing the degradation of natural habitats that generates biodiversity loss.
- 5) *Energy*: We source data on primary energy production from the International Energy Agency (IEA)⁷⁸ to develop the energy proxy, which includes primary energy production from 21 energy products that are grouped into six broad groups: Coal and peat (Anthracite, Coking coal, Other bituminous coal, Sub-bituminous coal, Lignite, Peat); Oil and natural gas (Oil shale and oil sands, Natural gas, Crude oil, Natural gas liquids, Other hydrocarbons); Nuclear (Nuclear energy); Solid biofuels (Primary solid biofuels); Captured energy (Hydro, Geothermal, Solar photovoltaics, Solar thermal, Tide, wave and ocean, Wind, Other sources), and Heat (Heat). Annex XI in the SCP-HAT - technical documentation⁷⁵ describes the allocation of these sources to MRIO table. This proxy is presented in the units of joules. This proxy has been linked to SDG 7 (Affordable and Clean Energy), in consideration that SDG 7's target 7.2 is relevant to the data used for constructing this proxy.
- 6) *Materials*: We source data on materials from the UN International Resource Panel Global Material Flows Database⁷⁹ which presents direct material flows for 124 different material categories that can be categorised into four broad materials groups: Biomass, metal ores, non-metallic minerals, and fossil fuels²⁶. This proxy is presented in the units of tonnes. This proxy has been linked to SDG 12 (Responsible Consumption and Production), in view of the material footprint being a UN proposed indicator for target 12.2 (*i.e.*, indicator 12.2.1) of SDG 12.
- 7) *Water stress*: We compile this proxy based on data on water use⁸⁰ combined with the AWARE characterisation factor⁸¹. AWARE is “*a midpoint indicator representing the relative Available Water REmaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met*”⁸². Development of this proxy is explained in detail in the SCP-HAT's technical documentation⁷⁵. This proxy is presented in the units of m³ H₂O-equivalent. This proxy has been linked to SDG 6 (Clean Water and Sanitation) under the consideration that water stress is proposed by the UN as an indicator (indicator 6.4.2) for this goal's target 6.4.
- 8) *Nitrogen emissions*: We cover three categories of nitrogen emissions: Nitrogen oxides (NO_x) and ammonia (NH₃) to air, and nitrogen (N) leached to freshwater. We characterise nitrogen flows to water based on the FAOSTAT's Climate Change Emissions domain⁸³. Nitrogen is deposited in oceans/waters through various means such as atmospheric deposition, runoff, and river transport. We then capture airborne nitrogen emissions based on the *GHG emission and air pollution* dataset as described above. We obtain nitrogen leaching information from the FAOSTAT Climate Change Emissions domain⁸³, encompassing data on nitrogen utilization and leaching to water. This proxy is presented in the units of tonnes. This proxy has been linked to SDG 14 (Life Below Water), given that nitrogen is a nutrient associated with eutrophication.

Eutrophication and marine nutrient pollution are explicitly mentioned in SDG 14's indicator 14.1.1 and target 14.1, respectively.

- 9) *Women's participation*: We distinguish employment by gender (male and female employment) based on data from the ILO⁸⁴, expressed in units of number of people. The ILO data feature more aggregated sectors than the GLORIA MRIO database, which are disaggregated using data on compensation to employees. The raw data for this proxy are then converted into a ratio by applying a weight of 0 to female employment and 1 to male employment, followed by normalisation by dividing the total number of males in the workforce with the total female and male workforce employed during 1990-2018. Thus, this resultant proxy corresponds to women's participation in the workforce, and it is expressed in the units of percentage of males employed. This process of conversion of data on male and female employment to a measure for the percentage of males is undertaken to express this as a negative proxy, in the sense that if the percentage of males increases in the workforce (as a proportion of the total workforce) then the percentage of females unavoidably decreases. A negative trend where the percentage of males decreases over time is thus considered a positive outcome for this indicator. This proxy was linked to SDG 5 (Gender Equality), considering that target 5.1 calls for the end of discrimination against women. In this sense, we assume that a low level of women's participation in the workforce constitutes discrimination of women.
- 10) *Labour skills*: We distinguished different levels of skills (high-, medium-, and low-skilled) based on data from the ILO⁸⁴. Allocation of these data to the MRIO database follow the same approach as the *women's participation* proxy described above, using data on compensation of employees. The raw data for this proxy can be defined as the number of people employed at the three skill levels, which we then transform into a ratio by applying the following weights: 1/3 for high-skilled, 2/3 for medium skilled and 1 for low-skilled workforce, followed by normalisation by dividing with the total workforce employed at all three skill levels. This resultant proxy indicator 'labour skills' is expressed in the units of percentage of low-skilled workforce. This process of conversion of labour skills data to a measure for the percentage of low-skilled workforce is undertaken to express this as a negative proxy in the sense that if the percentage of low-skilled workforce increases then the percentage of high- and medium-skilled workforce will decrease. This proxy has been linked to SDG 10 (Reduced Inequalities), given that SDG 10's target 10.1 argues for the income growth of the lower population percentiles. Since this proxy is based on employees' compensation, a negative trend where the percentage of low-skilled workforce decreases over time is considered a positive outcome for this indicator.
- 11) *Poverty*: In line with the UN System for Economic and Environmental Accounting⁸⁵, we construct the poverty proxy by representing individuals living below the poverty line (US\$1.90 per person per day), with the daily income per person estimated as the ratio of total income to employment⁸⁴. The income data are obtained from the value-added block of the GLORIA database. This proxy has been linked to SDG 1 (No Poverty) in units of number of people, considering that its target 1.1 seeks to eradicate extreme poverty (people living below the international poverty line). By accounting for the share of workers below the poverty threshold, a negative trend in this proxy represents a reduction in extreme poverty cases, and hence a contribution to SDG 1.
- 12) *Occupational accidents*: This proxy covers fatal and non-fatal accidents⁸⁶. ILO defines the former as those "*where workers were fatally injured as a result of occupational accidents*" or "*unexpected and unplanned occurrences arising out of or in connection with work*", and "*where death occurred within one year of the day of the accident*", and the latter as those "*where the workers injured were unable to work*" temporarily or permanently from the day after the day of the accident⁸⁶. This proxy is presented in the units of cases. This proxy has been linked to

SDG 8 (Decent Work and Economic Growth), taking into account that fatal and non-fatal injuries is the indicator (8.8.1) proposed by the UN to measure progress towards SDG 8's target 8.8.



Fig S2: Connecting SDGs to quantitative proxies.

A representative proxy for each SDG is presented in bold text.

3. Supplementary Results

We select 12 representative consumption-based proxies to cover environmental and social dimensions of sustainability linked to 12 unique UN SDGs (SDG1: No Poverty, SDG2: Zero Hunger, SDG5: Gender Equality, SDG6: Clean Water and Sanitation, SDG7: Affordable and Clean Energy, SDG8: Decent Work and Economic Growth, SDG10: Reduced Inequalities, SDG11: Sustainable Cities and Communities, SDG12: Responsible Consumption and Production, SDG13: Climate Action, SDG14: Life Below Water, and SDG15: Life on Land) and assess trends in outsourcing for 160 individual countries. We model outsourcing trends from 1990-2018 to assess polarising and equalising trends in international trade and SDGs from the territorial/producer perspective and those resulting from consumer demand of imported products (i.e. consumer perspective, footprints). This study focuses on overall global trends for a range of consumption-based proxies rather than single results for a particular year (see Fig S2 and *Methods – Connecting SDGs to primary factors of production*).

3.1. Energy

Energy resources are increasingly outsourced (Fig S3), with wealthy countries such as Norway, Australia and Saudi Arabia increasingly assuming a net-exporting role. Norway exported 9.52% of petroleum gases, the largest in the world in 2018⁸⁷. 50% of Australia's exports comprise of iron ore, coal, gas, and petroleum. Australia is the fifth-largest producer and the second-largest exporter of coal and has the third-largest reserves of coal in the world⁸⁸. Saudi Arabia is a top exporter of crude oil⁸⁹, given the country has the largest crude oil production capacity. Such concentration of energy reserves in parts of the world leads to polarising international trade relationships because at the core of outsourcing lies the issue of equity of availability of energy resources. Access to affordable and clean energy is essential to improving education and health outcomes, reducing poverty, and improving work opportunities^{90,91}. The greatest effects of reduced energy access occur in already poor, marginalised communities in the Global South. The 2022 World Energy Outlook reports that the COVID-19 pandemic and the current energy crisis caused by the Russia-Ukraine War will likely mean 100 million people, mostly in Sub-Saharan Africa and South-East Asia, and the Pacific (excluding Australia and New Zealand) can no longer cook with clean fuels⁹⁰.

In 2000, USA's demand for international imports resulted in 10.5 Exajoules (EJ) of energy consumption, representing 15% of its total energy consumption (import + domestic consumption). In comparison, the country's energy imports reached 18.6 EJ in 2018, contributing to more than 20% of its total energy consumption. Over the past 20 years, the largest exporter to the USA shifted from Japan to China, with the latter representing 2.9% of total US energy imports in 2000 and 16% in 2018.

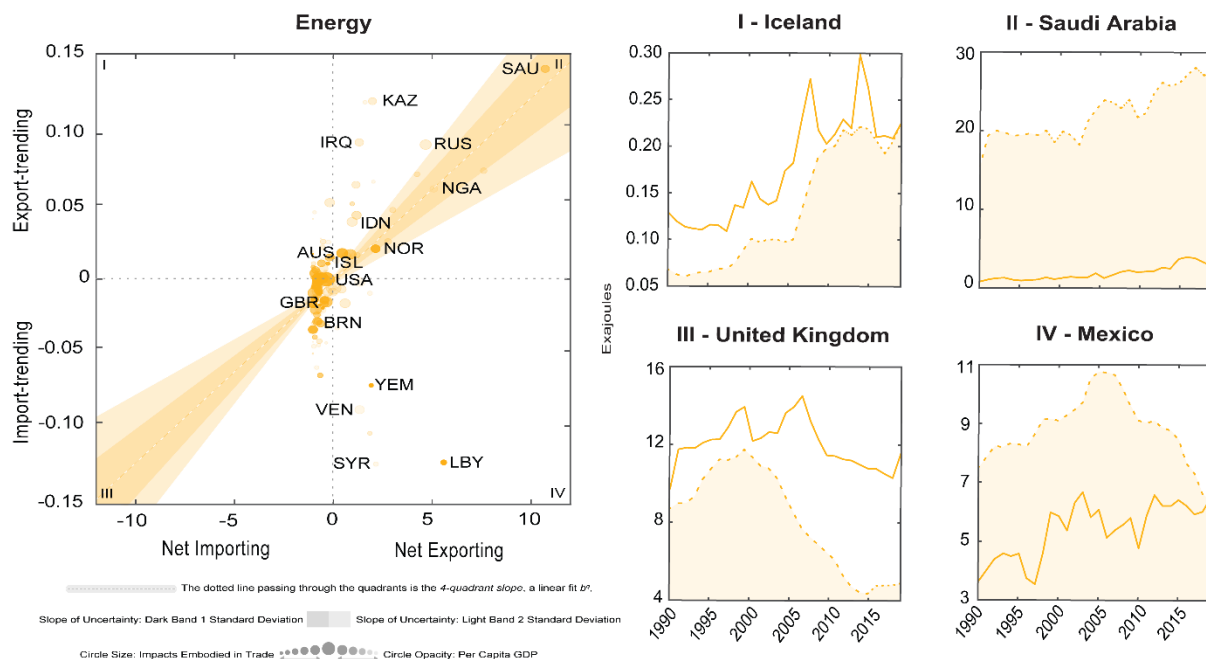


Fig. S3: Net importers and exporters of energy in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: UK); quadrant II shows export-trending net exporters (example: Saudi Arabia). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Iceland), quadrant IV shows import-trending net exporters (example: Mexico). Circle size represents energy embodied in trade, circle fill colour represents per-capita GDP.

3.2. GHG emissions and Air Pollution

As expected, due to the reliance on energy to produce goods, the GHG emission and air pollution proxies showed the starkest polarizing trend (Figs S4 and S5). Many developed countries continue to outsource goods produced in developing countries already experiencing degraded air quality. For example, the *World Air Quality Report 2021*, which highlighted the state of global air quality in 2021, shows high pollution rates in these countries that fall in net-exporting nations of GHG emissions (Fig S4)⁹². Astonishingly, eleven Indian cities featured in the list of the top 15 most polluted cities in Central and South Asia.

Twenty per cent of 2020 Chinese exports to the USA comprised computers and broadcasting equipment⁹³, relying on coal to produce the energy needed for manufacturing⁹⁴. In 2006, about 4-8% of emissions in China were driven by the production of exports for the USA⁹⁵. Mexico’s second largest export to the USA is also computers, representing 6.39% of total USA imports in 2020⁹⁶. Many industries in China and Mexico that produce the goods the USA imports, are dependent on fossil fuels for their energy. Fossil fuels cause significant air pollution, both GHGs and other pollutants such as fine particulate matter, PM2.5. PM2.5 causes known health issues, including higher infant mortality⁹⁷.

Air pollution is a significant global public health issue, especially in the Global South^{98,99}. According to the World Health Organisation (WHO), around 89% of premature deaths due to air pollution occur in low-medium income nations, most of which are in the Global South¹⁰⁰. It is also well-known that GHG emissions are the main contributor to increasing global temperatures driving climate change. Climate change-related impacts, such as sea level rise and extreme weather, disproportionately affect the Global South. Climate change is also linked to health impacts^{101,102}, biodiversity loss¹⁰³, water stress¹⁰⁴, migration and conflict¹⁰⁵.

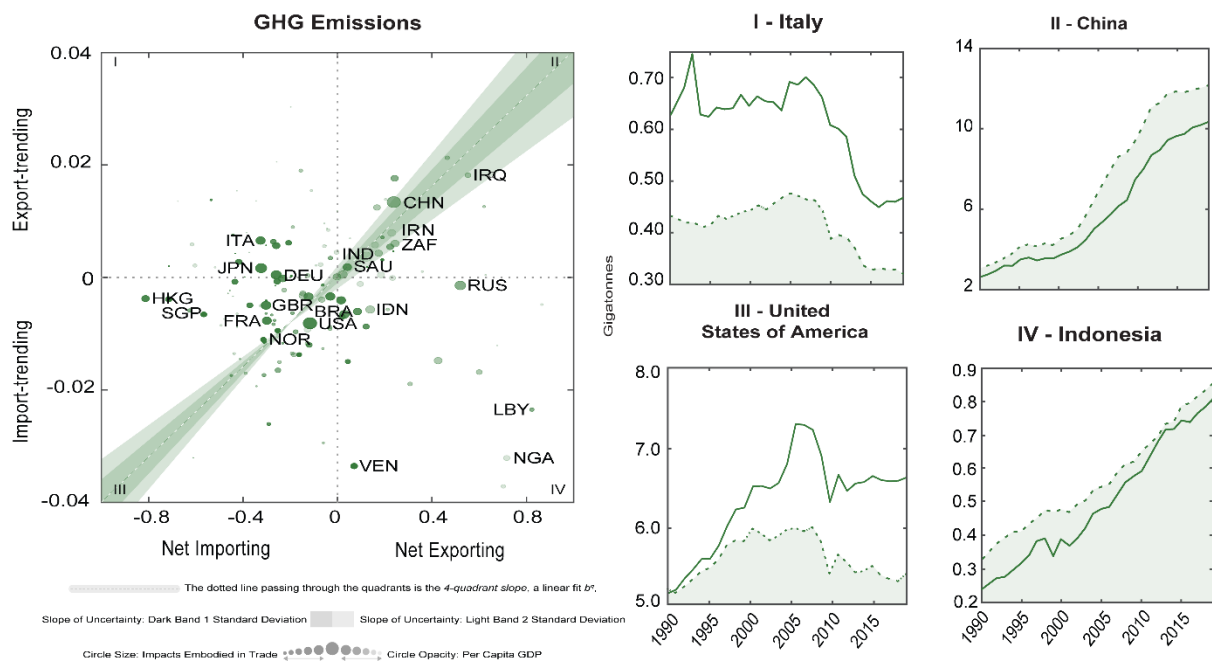


Fig S4: Net importers and exporters of GHG emissions in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: USA); quadrant II shows export-trending net exporters (example: China). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Italy), quadrant IV shows import-trending net exporters (example: Indonesia). Circle size represents GHG emissions embodied in trade, circle fill colour represents per-capita GDP.

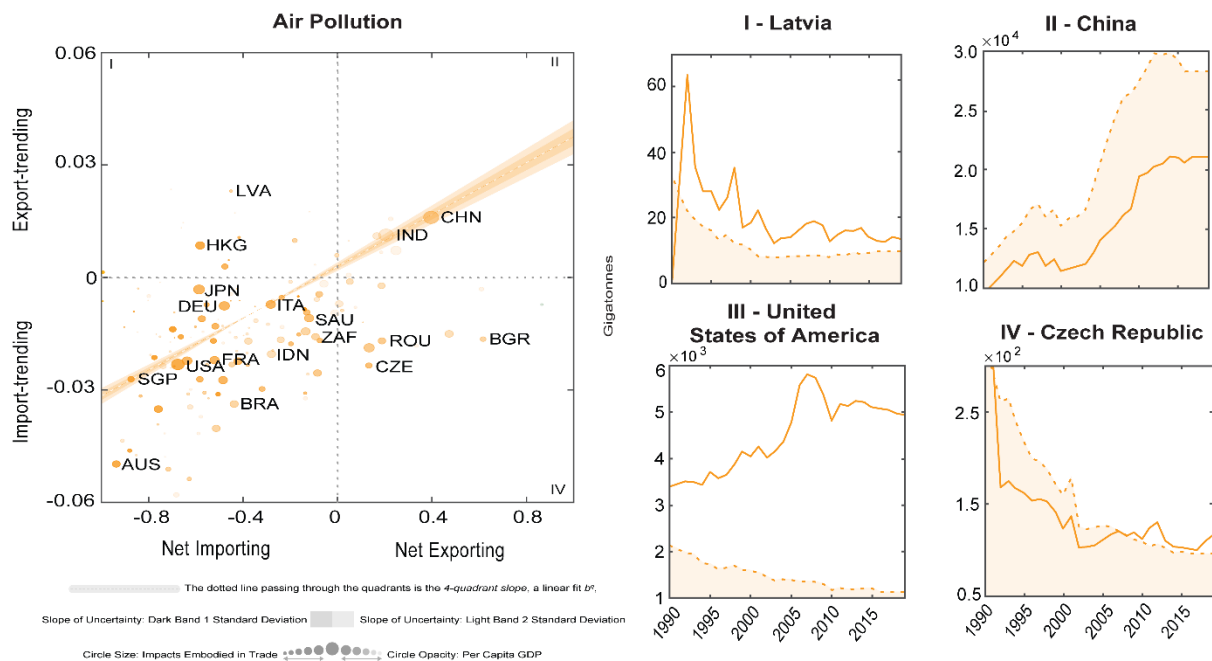


Fig S5: Net importers and exporters of air pollution in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: USA); quadrant II shows export-trending net exporters (example: China). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Latvia), quadrant IV shows import-trending net exporters (example: Czech Republic). Circle size represents air pollution embodied in trade, circle fill colour represents per-capita GDP.

3.3. Water stress

MRIO analysis has been previously used for quantifying water embodied in trade¹⁰⁶. Shortage of water due to hydrological conditions, the lack of adequate water infrastructure or overconsumption can result in a condition known as water stress (the term ‘water scarcity’ is used synonymously in this study)¹⁰⁷. The World Resources Institute has developed a Water Risk Atlas¹⁰⁸ that identifies and evaluates water risk at a global level. Countries in the Middle East and Africa are primarily affected¹⁰⁹, as these regions receive less rainfall in comparison to other world regions and are densely populated¹⁰⁷. Eleven countries in the Middle East and North Africa are in the top seventeen most water-stressed regions globally¹⁰⁷, grappling with various drivers of water stress, such as conflict, climate change, population growth, and poor water resource management¹¹⁰. Water stress is expected to worsen under climate change, pushing an additional 1.8 billion people into moderate to severe water stress conditions, and 80% of which reside in developing regions¹⁰⁴.

Out of the top 10 trading partners France imports from, three are experiencing high water stress¹⁰⁹: Italy, Spain and Turkey¹¹¹. Vehicles (e.g., cars, trucks) make up a large percentage of the imports into France from these trading partners; with the country being the fourth largest importer of cars in the world¹¹². Car manufacturing is a water-intensive process¹¹³, with an estimated 150,000 litres of water used in the production of one car¹¹⁴. This is a clear example of consumer demand exacerbating water scarcity, with international trade putting pressure on water resources in producing countries¹¹⁵. Turkmenistan is an interesting case worth mentioning: the country relies on water from the Amu Darya, a river supplied by permafrost runoff¹¹⁶, with 95% of the water from the river used in agriculture¹¹⁷. 76% of irrigated land is saline due to mis-management and the country is categorized as under extremely high baseline water stress¹⁰⁹. This has wide-ranging implications for the country’s population (most of which are reliant on agriculture as their main income source) and exports (for example, of cotton that is a high water-consuming crop and a key agricultural export commodity of Turkmenistan)¹¹⁸.

Saudi Arabia is another interesting case for SDG 6: a country classed under extremely high baseline water stress¹⁰⁹, it is an import-trending net-importer, thus demonstrating a polarising trend (Fig S6). This is due to two reasons: a) Saudi Arabia is a net-importer of agricultural products¹¹⁹, which are associated with water stress. In 2020, the country imported \$22.5 billion USD of agricultural products whilst exporting \$4.33 billion USD¹²⁰; b) implementation of domestic policies for easing water stress domestically. Saudi Arabia has led the way to address water scarcity by introducing the Qatrah (“droplet” in Arabic) program for setting water conservation targets and rationalising water use¹²¹.

Our results show that Australia is an import-trending net exporter - the country has faced water stress over multiple periods of drought, which has food security implications¹²². Mali is demonstrating an export-trending net importer status. About half of the country’s population lives below the poverty line¹²³, where climate change has been putting pressure on the water resources¹²⁴ and the country relies heavily on its gold and cotton exports¹²⁵, 82.9% and 6.7% of total exports in 2020, respectively.

Tunisia is experiencing polarising trends as an export-trending net-exporter. Water scarcity in Tunisia has impacted socio-economic development and has led to overexploitation of groundwater resources¹²⁶. Tunisia’s key exports include electrical equipment, olive oil, clothing, with EU and the USA being key trading partners¹²⁷. Water scarcity is set to worsen in Tunisia in the face of climate change¹²⁸ - by 2025, the area utilised for rain-fed crop is projected to decrease by 30%¹²⁹. Furthermore, Tunisia is listed as a high baseline water stress country in the National Water Stress Ratings by the World Resources Institute

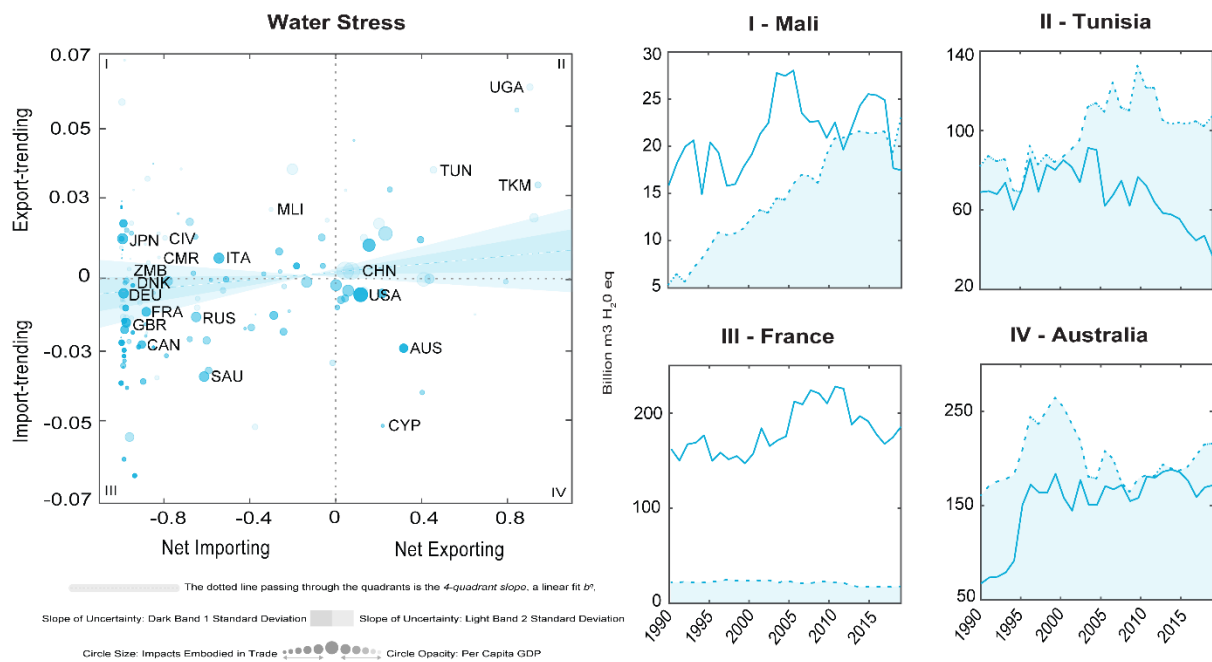


Fig S6: Net importers and exporters of water stress in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: France); quadrant II shows export-trending net exporters (example: Tunisia). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Mali), quadrant IV shows import-trending net exporters (example: Australia). Circle size represents water stress embodied in trade, circle fill colour represents per-capita GDP.

3.4. Materials

Materials (including biomass and fossil fuels) form the basis of our everyday lives. Mineral-rich countries are net-exporters and are continuing to maintain their status. Australia (export-trending net-exporter, Fig S7) has experienced periods of mining booms, with the most recent in the mid-2000s driven by demand from India and China¹³¹. In 2010, Australia was the world’s leading producer of key minerals, such as bauxite and rutile; and featured in the top-5 leading producers for production of uranium, lead, ilmenite, zircon, iron ore, zinc, black coal, gold, manganese and nickel and even diamonds and silver¹³². Mineral exploration has been increasing in Australia since 2014 for all metals/minerals except for coal, which is steady between 50-100 million AUD¹³³. Canada is also an export-trending net-exporting nation, as the country is a global producer of copper, nickel, cobalt, and critical minerals¹³⁴, fueled by the increase in demand for critical minerals needed for the energy transition¹³⁵. As such, the Government of Canada has put out a critical minerals strategy to further boost this crucial economic sector of the nation¹³⁵. The close relationship between the United States and Canada has also led to the signing of the Joint Action Plan on Critical Minerals Collaboration¹³⁶ for maintaining a sustainable supply of minerals for aerospace, telecommunications, and clean energy industries.

Many trends across Japan, South Korea and Saudi Arabia, are due to external influences. Japan’s observed trends are largely due to the Lost Decade¹³⁷; a period of slow growth and recession in the 1990s/early 2000s leading to fluctuating import demand for mineral resources rather than a steady increase¹³⁸. South Korea, a net importer and import-trending nation, faced national financial crises in 1997, when South Korea’s period of high economic growth came to a halt¹³⁹. This impacted South Korea’s economy, which further hit during the 2008 Financial Crisis (see dips in Fig S7, panel III for 1997 and 2008¹⁴⁰). Saudi Arabia joining the World Trade Organization in 2005¹⁴¹ meant that the country had greater access to global markets¹⁴², and imports increased substantially from 2005-2010¹⁴³. The gap

between domestic material use and production; and that from imports narrowed substantially after 2005 (Fig S7, panel IV).

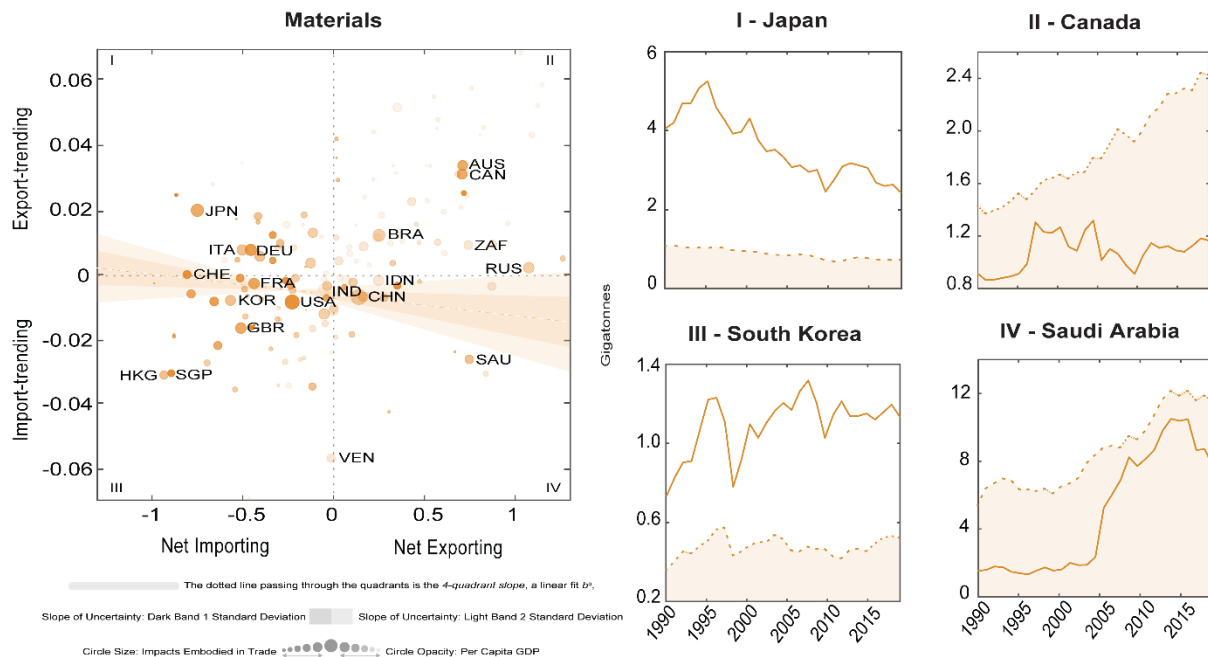


Fig S7: Net importers and exporters of materials in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: South Korea); quadrant II shows export-trending net exporters (example: Canada). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Japan), quadrant IV shows import-trending net exporters (example: Saudi Arabia). Circle size represents materials embodied in trade, circle fill colour represents per-capita GDP.

3.5. Land and Biodiversity

Domestic events often influence outsourcing trends. A classic example of this is Argentina (Fig S8): During a depression between 1998-2002¹⁴⁴, imports of agricultural products and associated land use associated with them dropped drastically¹⁴⁵. Production and exports of soybeans increased substantially after the depression¹⁴⁶. India is a net-importer trending toward imports (Fig S8). This can be explained by India’s increasing imports of vegetable oils and wood in recent years¹⁴⁷⁻¹⁴⁹. The gap between imports and exports is narrowing in Bolivia (Fig S8, panel IV), marked by a recent growth in imports after the global financial crisis in 2009; and driven by the increased purchasing power of the population¹⁵⁰. Given the constraints on land use expansion in Europe, land area used for agricultural production has remained steady over the past decade¹⁵¹. This has been coupled with the rapid intensification of European agricultural systems and a decline in small farms¹⁵¹⁻¹⁵³.

Land use (Fig S9) is coupled with the biodiversity loss proxy, given that land use change often results in habitat loss, which itself is a prominent cause for many species threats. The adverse effects of land use and land use change are well-documented¹⁵⁴, including unsustainable agriculture as a key driver of biodiversity loss. Habitat loss caused by anthropogenic activities has reduced terrestrial habitat integrity by 30%, relative to an unimpacted baseline¹⁵⁴. Undoubtedly, habitat loss threatens species, and the situation is set to deteriorate unless urgent actions is taken, as modelled in future scenarios of climate change^{155,156}. Human activities, including food production, have resulted in an overuse of the Earth’s biocapacity by at least 56%¹⁵⁷.

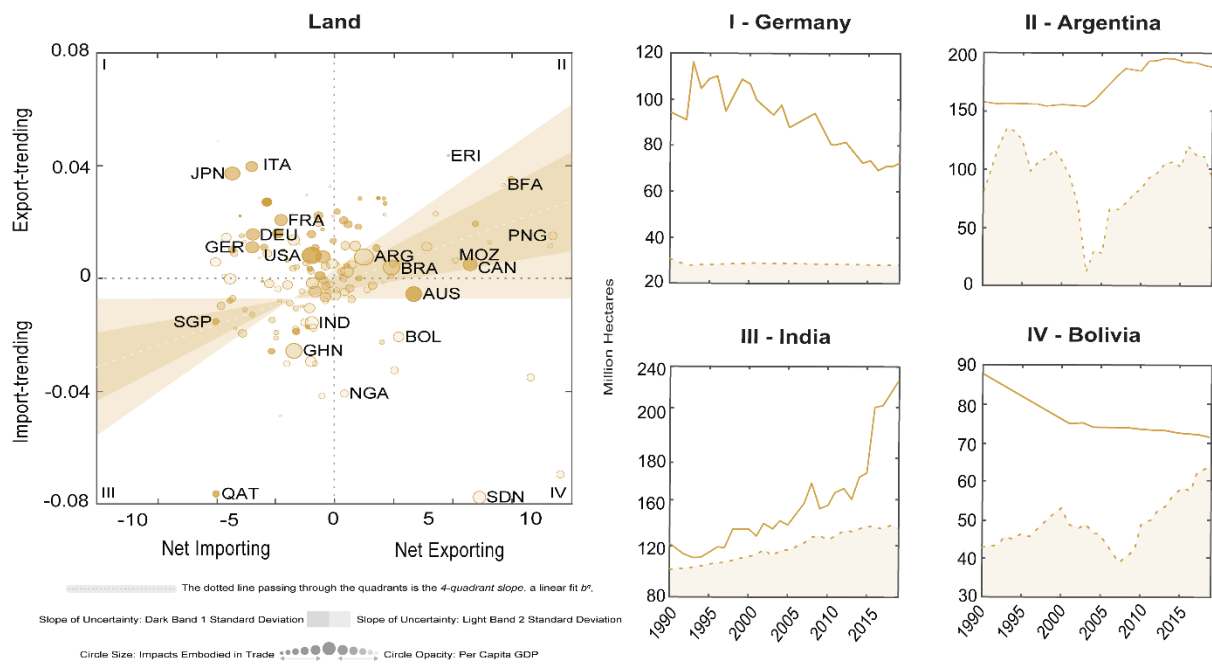


Fig S8: Net importers and exporters of land use in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: India); quadrant II shows export-trending net exporters (example: Argentina). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Germany), quadrant IV shows import-trending net exporters (example: Bolivia). Circle size represents land embodied in trade, circle fill colour represents per-capita GDP.

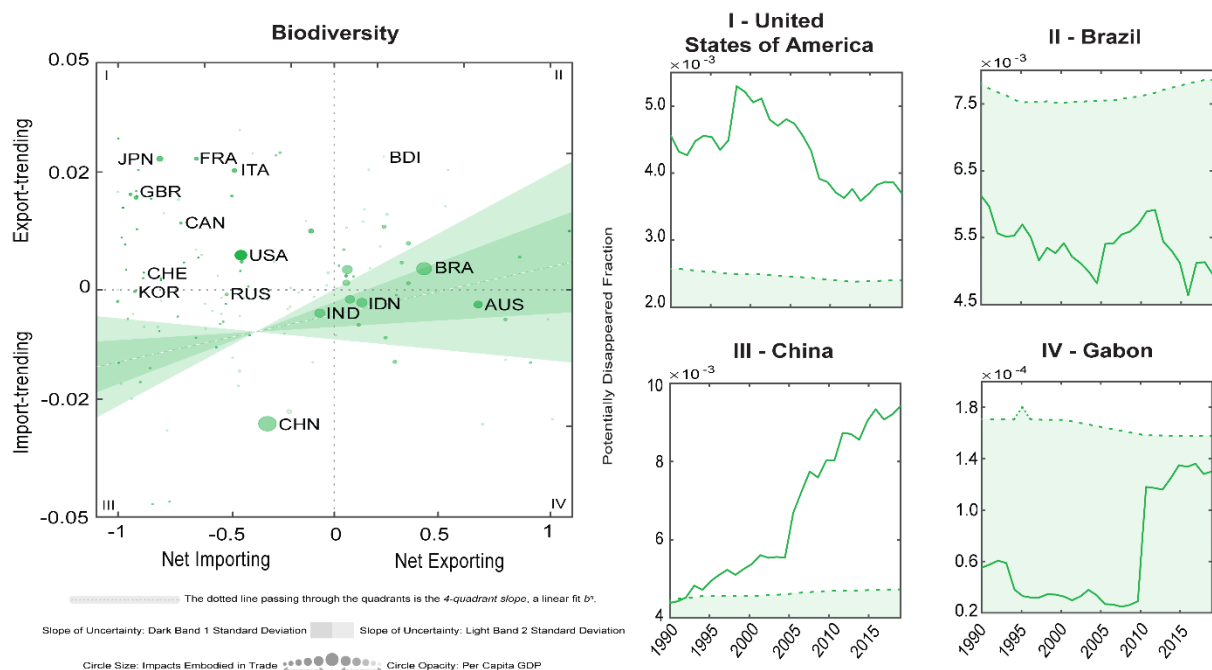


Fig S9: Net importers and exporters of biodiversity impacts in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: China); quadrant II shows export-trending net exporters (example: Brazil). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: United States of America), quadrant IV shows import-trending net exporters (example: Gabon). Circle size represents biodiversity impacts embodied in trade, circle fill colour represents per-capita GDP.

3.6. Nitrogen

Human activities result in emissions to air and water, including ammonia and nitrogen oxides from fertilizers to air and nitrogen leached to freshwater. These pollutants have wide-ranging consequences for public health¹⁵⁸ and the environment¹⁵⁹. Consumer demand has dramatically increased nitrogen emissions, largely due to increased demand for products that embody nitrogen emissions and the growing global population. Excess nitrogen leads to environmental degradation, such as reduced water quality due to eutrophication¹⁶⁰ – an issue commonly found in developing countries¹⁶¹.

China's growing industry sectors have resulted in a drastic rise in the release of nitrogen compounds into the environment¹⁶². Nitrogen deposition in the country has increased by 60% between 1980 and 2010¹⁶³. Japan is an interesting case, being one of the net-importers of nitrogen (Fig S10, panel I) embodied commodities¹⁶⁴, is export-trending. One of the reasons is a decrease in imports from the USA. The exports from the USA to Japan have decreased at an annualised rate of 0.22%¹⁶⁵, which is further coupled with a decrease in nitrogen dioxide emissions in the USA¹⁶⁶, hence a decrease in emissions embodied in trade between the USA and Japan.

Brazil is experiencing polarising trends. Nitrogen sustainability in Brazil is categorised as weak-to-basic level of sustainability¹⁶⁷ with an increase in nitrogen inputs in the country¹⁶⁸; the demand for food and energy are linked to this unsustainable outcome.

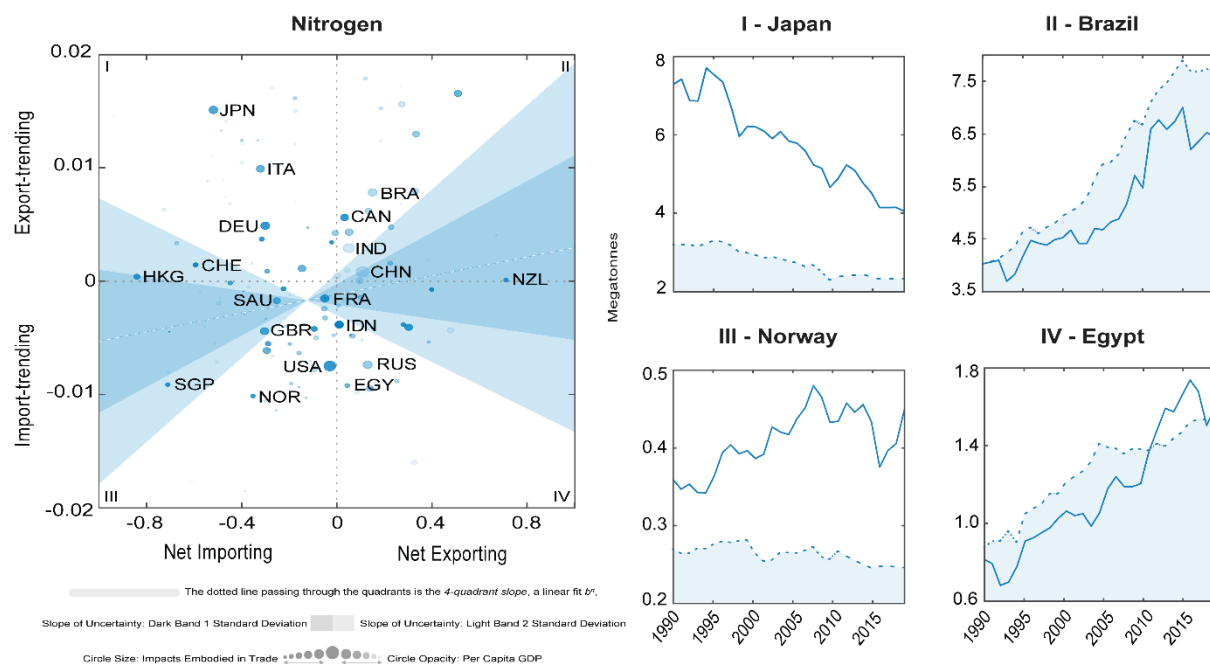


Fig S10: Net importers and exporters of nitrogen emissions in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: Norway); quadrant II shows export-trending net exporters (example: Brazil). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Japan), quadrant IV shows import-trending net exporters (example: Egypt). Circle size represents nitrogen emissions embodied in trade, circle fill colour represents per-capita GDP.

3.7. Women's Participation and Labour Skills

Women's participation in the Global South is much lower compared to the Global North due to existing laws banning women from work or societal stigma¹⁵. Low rates of women participating in the workforce also adversely affect economic growth: A report by the International Monetary Fund finds that legal

restrictions on women's participation in economic activities in countries like Angola and Cameroon are a key factor in explaining the growth differential with the Asian countries¹⁶⁹.

In developed nations such as Australia (a net-importer, Fig S11), women comprised almost 50% of the workforce in 2020 compared to 30% in 1966. These changes have occurred with greater working opportunities, access to parental leave, and more flexible working arrangements¹⁷⁰. Some government-led policies have supported companies' hiring of women by, for example, making it mandatory for private sector employers with over 100 employees to report to the Workplace Gender Equality Agency¹⁷¹. From a trade perspective, domestic situation in Australia has improved over time, making the country an import-trending net-importer (Fig S11).

Similarly, in the Netherlands (an import-trending net-importer, Fig S11, panel III), female participation in work has grown, however most of the increase was in part-time employment. The Government of the Netherlands introduced a female hiring quota for women for Dutch stock exchange listed companies. Additionally, the largest 5000 companies in the Netherlands must report the results of various gender equality targets to the Social and Economic Council¹⁷². Part-time work culture is not confined to low-skilled jobs only. Over 25% of workers in highly skilled managerial, professional and technical occupations also work part-time, which is twice the OECD average for people in these roles¹⁷³. An empirical analysis of trends for female participation in the workforces of African countries shows that female education, GDP per capita, fertility, manufacturing growth rate and culture influence the supply of female labour in the continent¹⁷⁴. In Yemen, the female unemployment rate is twice that of men¹⁷⁵, and out of all working-age women in Yemen less than 5% were employed as reported in a survey by the International Labour Organisation (ILO)¹⁷⁵. The ongoing conflict has had devastating consequences on women's participation as well¹⁷⁶.

A rare example of an equalising trend is established by Afghanistan (Fig S11, panel IV). Starting with the ousting of the Taliban in 2001, domestic women's participation increased until it was on par with that of Afghanistan's trading partners from 2015 onwards.

It is well known that wealthy countries have been and continue to outsource lower-skilled labour work to countries such as India and China. For example, on the back of its Information Technology revolution, Ireland has markedly increased the proportion of skilled work, partly at the expense of countries such as Angola, where lack of qualified workforce is an issue¹⁷⁷. Papua New Guinea has had an interesting labour history, marked by a series of reforms^{178,179}, where the percentage of low-skilled workforce has decreased over time (Fig S12, panel IV).

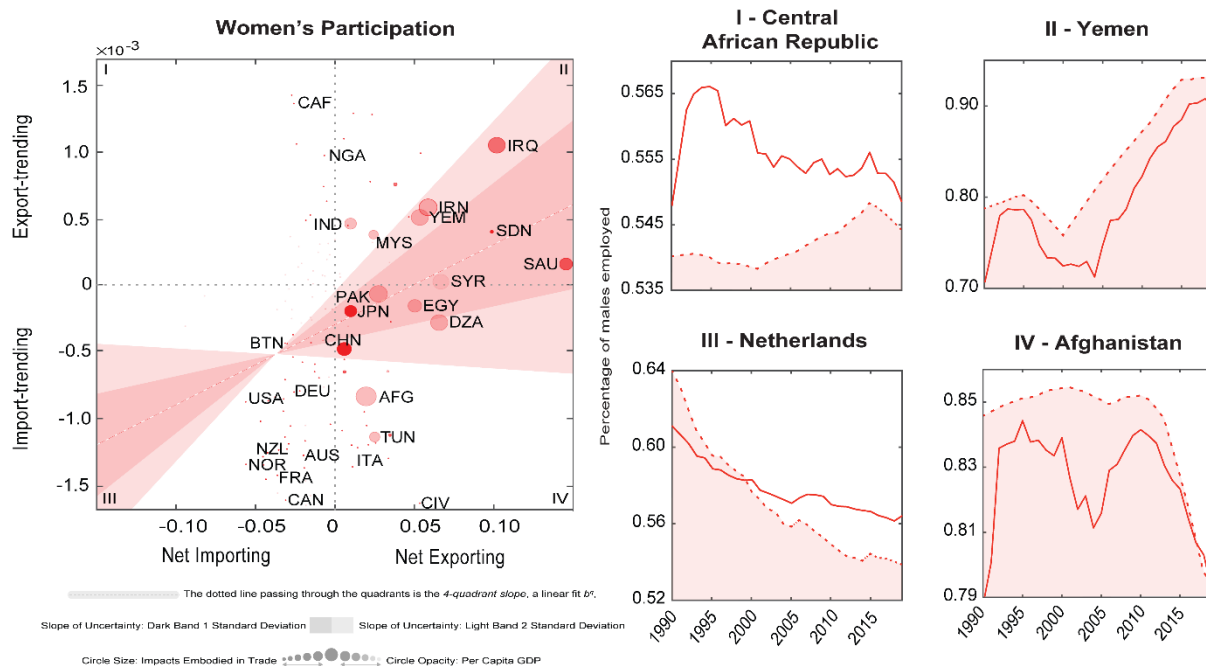


Fig S11: Net importers and exporters of women's participation in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time ("import-trending", example: Netherlands); quadrant II shows export-trending net exporters (example: Yemen). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Central African Republic), quadrant IV shows import-trending net exporters (example: Afghanistan). Circle size represents men's labour participation embodied in trade, circle fill colour represents per-capita GDP.

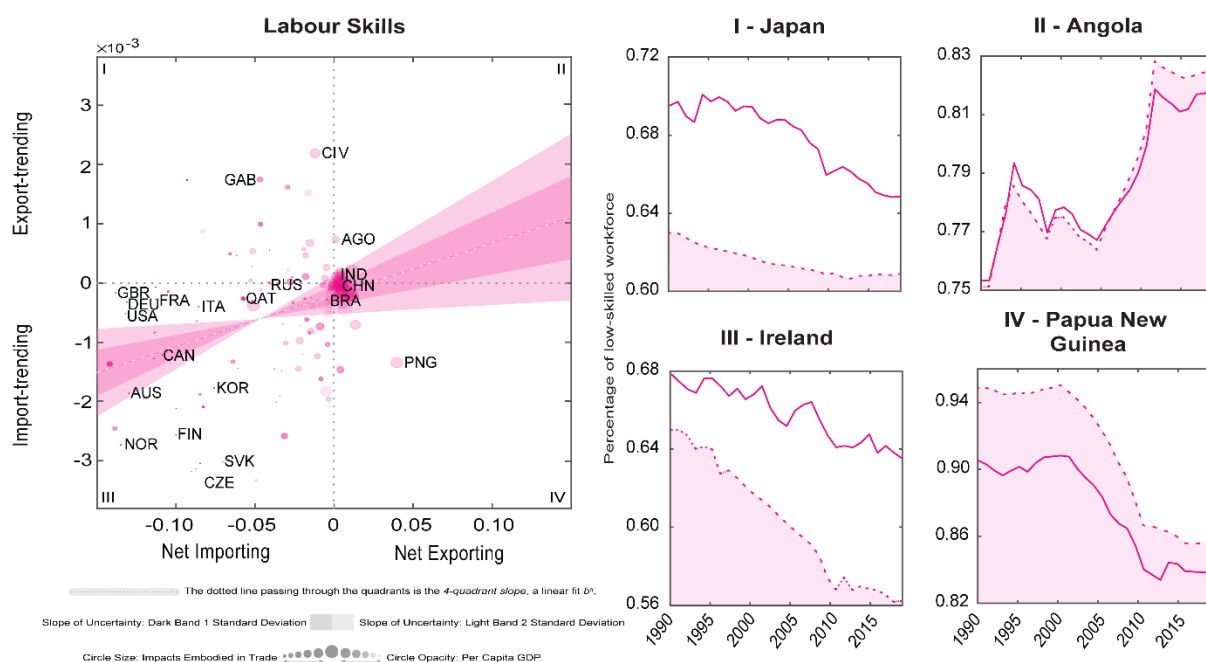


Fig S12: Net importers and exporters of labour skills in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time ("import-trending", example: Ireland); quadrant II shows export-trending net exporters (example: Angola). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Japan), quadrant IV shows import-trending net exporters (example: PNG). Circle size represents unskilled labour embodied in trade, circle fill colour represents per-capita GDP.

3.8. Poverty

The greatest challenges to achieving zero poverty are in the Global South due to a lack of resources for social support and ongoing internal conflicts¹⁵. Poverty has significant adverse socio-economic impacts, including lower health outcomes and life expectancy¹⁸⁰. Positive outcomes in adulthood are impeded for children who grow up in poverty, creating a vicious cycle of entrapment¹⁸¹. Generally, global poverty is declining, demonstrating equalizing trends, except for several conflict-affected areas in the Middle East and North Africa, which experienced a 7.1 percent increase in poverty in 2018¹⁸². Poverty in Zimbabwe has increased, with wide-ranging dimensions; from income to health and education¹⁸³. The trend observed for Qatar (Fig S13) is due to either an increase in trade activities with countries that have seen an increase in the number of people living in poverty¹⁸⁴ or the initiation of new trade relationships with countries that have a greater proportion of poor people than those in Qatar's previous trading partners.

In Bangladesh, poverty has declined. Of recent poverty numbers, the rural areas in Bangladesh were responsible for 90% of national poverty reduction between 2010-2016. The driving forces behind Bangladesh's poverty reductions include economic growth, lower fertility rates, education gains, and higher incomes. International trade has played a significant role in both alleviating and exacerbating poverty. International trade fosters economic and social benefits¹⁸⁵. According to the World Bank, countries with open international trade policies grow faster, providing their people with higher incomes and more opportunities¹⁸⁵. Trade drives faster productivity growth, especially for sectors and countries engaged in global value chains (GVCs), enabling developing countries to specialize in one part of the value chain¹⁸⁶. GVCs enable access to foreign technology and investment, which is essential to economic growth¹⁸⁷. Between 1995 and 2015, developing countries saw a significant increase in their contributions to the global GDP, rising from 20% to 39%. Their share of global merchandise exports also increased from 25% to 46% in the same period. Furthermore, the percentage of people living in extreme poverty decreased from 36% in 1990 to 10% in 2015¹⁸⁸. It is worth mentioning that the contribution of economic growth and education gains to poverty reduction is shifting. For example, economic growth initially drove poverty reduction, yet now, GDP growth continues to accelerate while poverty has stagnated, with some areas (e.g. Western divisions) experiencing an increase in poverty while others (e.g. Eastern divisions) experiencing a decrease¹⁸⁹. Concerning Bangladesh, the World Bank hailed Bangladesh as a "model for poverty reduction"; given the country's progress in accelerating growth and creation of new jobs for the younger generations^{190,191}.

Japan's trends demonstrate that it is importing fewer products from poverty-stricken regions (Fig S13, panel I). This is largely due to its trade with China, which dramatically reduced its national poverty levels¹⁹². From 1995 to 2020, exports from China to Japan have increased 7.36% per annum¹⁹³.

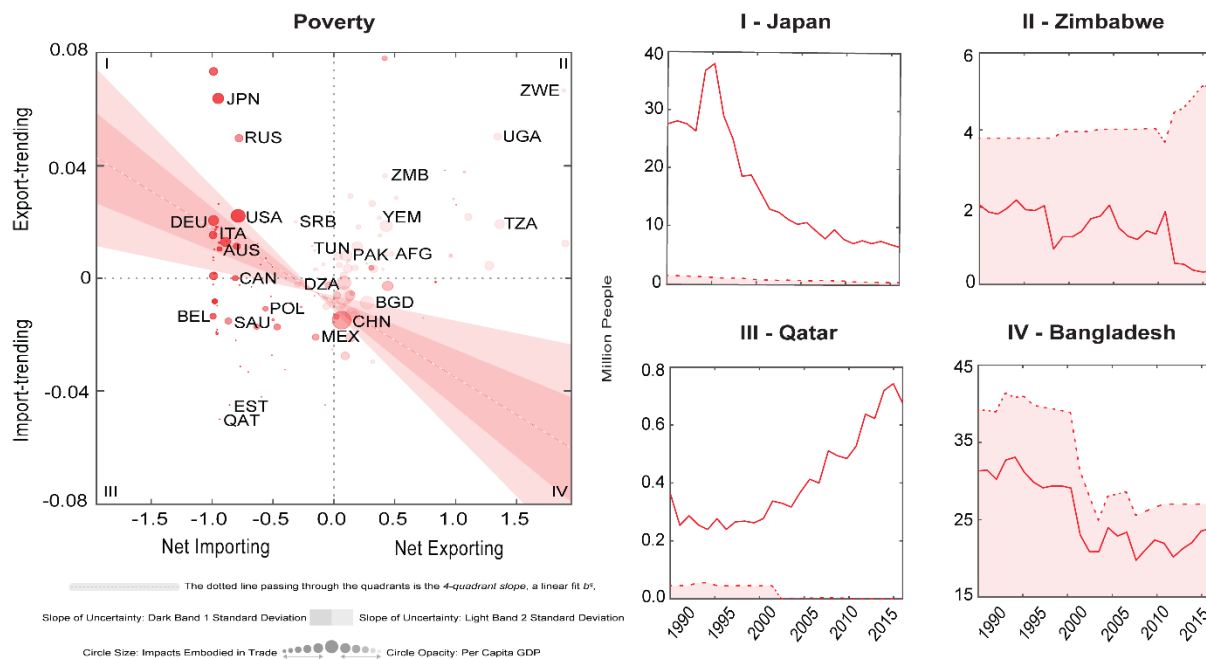


Fig S13: Net importers and exporters of poverty in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: Qatar); quadrant II shows export-trending net exporters (example: Zimbabwe). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Japan), quadrant IV shows import-trending net exporters (example: Bangladesh). Circle size represents poverty embodied in trade, circle fill colour represents per-capita GDP.

3.9. Occupational Accidents

Workplace safety is an important facet of decent work. The ILO classifies occupational hazards as fatal and non-fatal. Fatal and non-fatal occupational hazards create cascading socio-economic impacts, including lowered economic productivity, reduced household income, and increased risk to exploitation¹⁹⁴. The highest incidences of occupational hazards occur in the Global South, where labour protections and workplace health and safety regulations are lacking¹⁹⁵. Disease-related occupational risks in the Global South represent the largest share of fatalities¹⁹⁶. Some estimates show that the economic costs of work-related injury and illness vary between 4 and 6% of gross domestic product (GDP)^{194,196}.

In 2020, Cyprus imported \$11.2 billion USD of products and exported \$4.28 billion USD¹⁹⁷; given this big trade gap, it is unsurprising that Cyprus is a net-importer of commodities linked with occupational accidents as inherently there would be imported commodities (e.g. manufactured products) linked with fatal and non-fatal occupational accidents (Fig S14, panel I). France, also a net-importer, relies heavily on imports from within EU and outside of the EU; a key contributor of fatal and non-fatal accidents abroad as shown for the case of demand for textile products⁴² (Fig S14, panel III). Industries that are primarily prone to fatal and non-fatal occupational accidents usually include agriculture and construction/manufacturing¹⁹⁸. Workers in small-scale industries in Gampaha and Kalutara districts in Sri Lanka, namely food and beverages, apparel, non-metallic mineral products, and fabricated metal products, typically face health-related issues (such as skin burns, eye problems, headaches, chest pain and much more)¹⁹⁹.

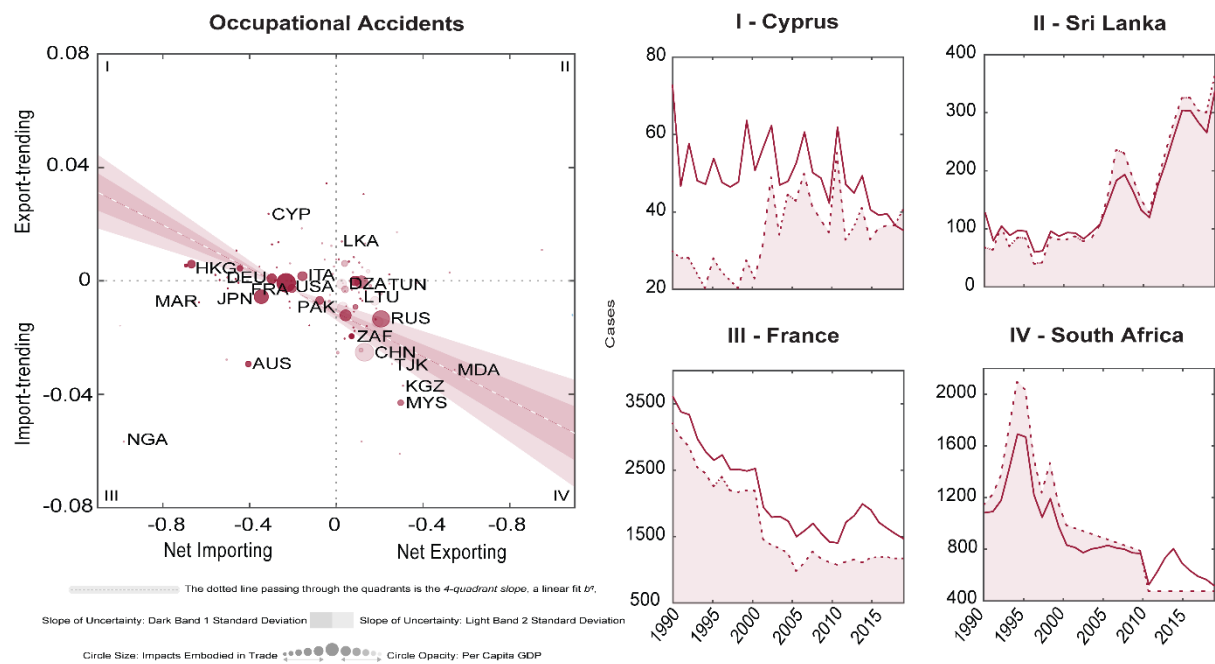


Fig S14: Net importers and exporters of occupational accidents in a 4-quadrant perspective. There are two quadrants representing *polarising trends*: Quadrant III shows net importers whose net-import position is increasing over time (“import-trending”, example: France); quadrant II shows export-trending net exporters (example: Sri Lanka). There are two quadrants representing *equalising trends*: Quadrant I shows export-trending net importers (example: Cyprus), quadrant IV shows import-trending net exporters (example: South Africa). Circle size represents occupational hazards embodied in trade, circle fill colour represents per-capita GDP.

4. Uncertainty analysis

Several countries have never produced a national input-output table, which poses problems for any MRIO-construction undertaking. However, these countries are not without sectoral data – for example, the United Nations Official Country National Accounts²⁰⁰, UNIDO’s MINSTAT²⁰¹ and INSTAT²⁰² database, FAOSTAT²⁰³ and FishSTAT²⁰⁴, as well as United Nations Main Aggregates²⁰⁵ include sectoral data for nearly all ISO-coded countries, mostly on final demand and value-added. In addition, many countries have at least issued input-output tables two or three times during the past three decades.²⁰⁶ In our MRIO construction pipeline, relative sector sizes from those years with data availability become imprinted in other years, as one year’s MRIO table serves as the initial estimate for the following year’s constrained optimisation process²⁰⁶. Third, for those countries without input-output table exists, a scaled production recipe is estimated from a mix of the very detailed Japanese, US and Australian IO tables²⁰⁶. Production recipes for a particular commodity do not vary overly and arbitrarily between countries as, for example, one needs tyres for a certain proportion of cars’ production input, flour for bakery products, livestock for meat products, bauxite for aluminium, and so on.^{207,208} This means that the input-output tables for countries without primary data are estimated from alternative data sources (see Table S2 for a list of data sources used in the construction of the MRIO used in this study). These estimation procedures carry with them a certain level of uncertainty.

As with the Eora MRIO, GLORIA is equipped with standard deviation estimates. These are derived for standard deviation estimates for primary data.²⁰⁹, using Monte-Carlo analysis, a technique well established in the input-output research domain for this purpose.^{210,211} Most importantly, as can be intuitively understood from the laws around error propagation^{212,213}, the relative standard deviation of a sum of many summands – as is the case for the products of physical intensity, Leontief inverse and final demand – is much smaller than the individual factors’ relative standard deviations, intuitively because variations in different directions cancel each other out.

We have demonstrated this quantitatively for this study by including a Monte-Carlo analysis, in which we perturb the input-output system multiple times (for a mathematical treatment of the perturbation see ref. ²⁰⁹) and, each time, re-calculate all points in the four-quadrant graphs. These “perturbed” four-quadrant points will deviate from the original, unperturbed results shown in the main text. The magnitude of these deviations from many Monte-Carlo runs estimates the standard deviations of our four-quadrant results, as shown in Fig S15.

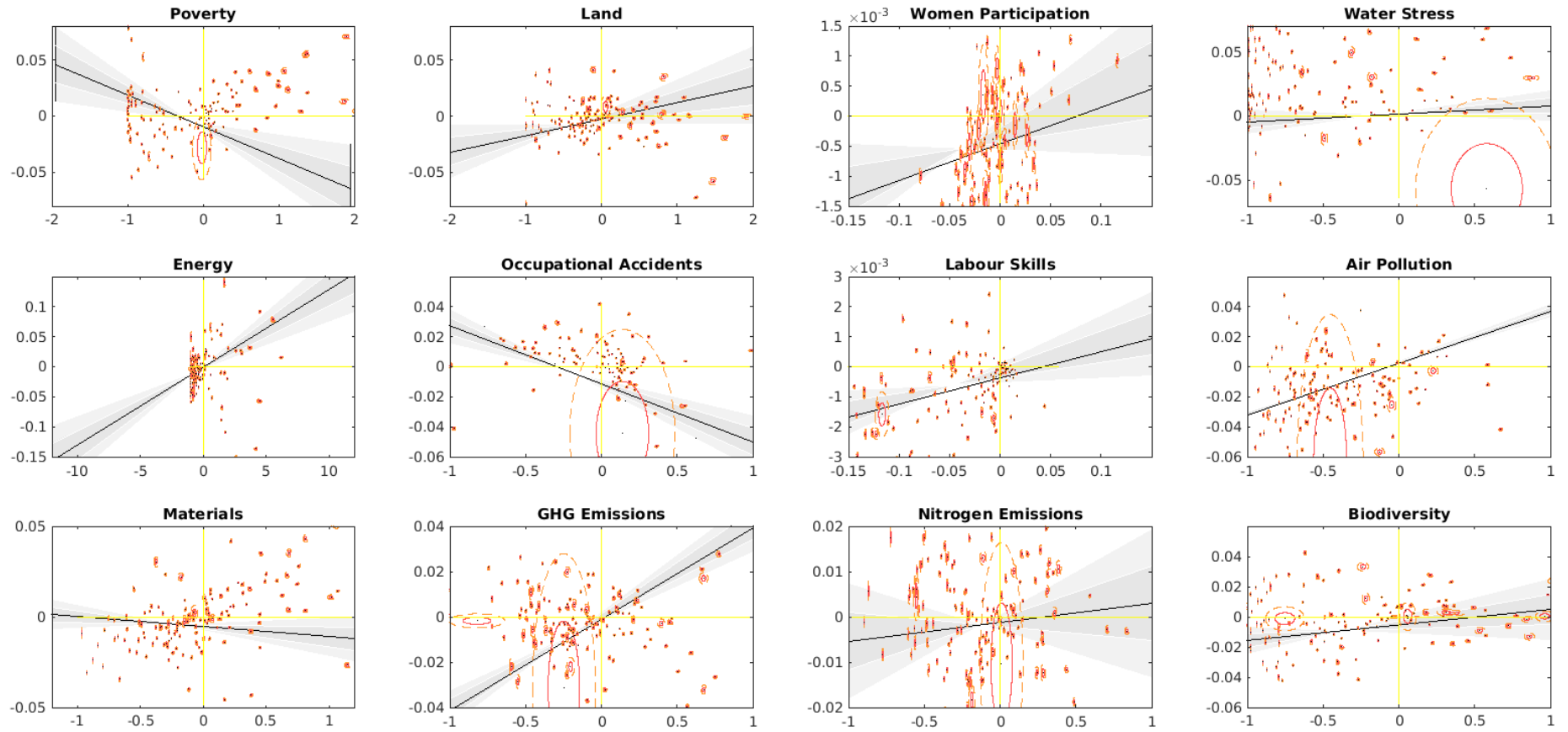


Fig S15: Result of Monte-Carlo runs in which perturbed input-output systems were used to calculate perturbed four-quadrant results. Each of those results is now represented by two concentric ellipses, representing the 1- σ (red solid ellipses) and 2- σ (orange dashed ellipses) uncertainty ranges. New perturbed slopes were calculated from the perturbed four-quadrant points. The mean of those perturbed slopes is indicated by the black solid lines, and the 1- σ (red solid ellipses) and 2- σ (orange dashed ellipses) uncertainty ranges were calculated as well. Large ellipses are spurious outliers for some countries with almost lacking information, e.g. Turkmenistan or People's Republic of Korea.

Table S2: The data sources presented in this table are primary data that are imposed on MRIO elements as constraints, ranked in descending order of priority as applied in the overall reconciliation. Data that are temporally, regionally and sectorally complete are taken as superior data that override less internally consistent data sources in the reconciliation process. The table below has been adapted from GLORIA Release Notes 059⁵³.

Data source	Reference	Years	Regions	Sectors
IO balance	n.a.	1990-2028	all	All
National Accounts Main Aggregates	205	all ¹	all	None
Food balances	214	1990-2019	all	Food-related sectors only
	215	1991-2020	150 ^{3,4}	Food-related sectors only
Compensation of employees	200	1990-2017	128 ⁵	Totals ¹⁶ only
Wages	216	all ¹	71 ⁶	≤ 21 (ISIC sections)
	217	1990-2008	52 ⁷	Totals ¹⁶ only
Employment	218	1992-2020	107 ⁸	≤ 88 (ISIC divisions)
	217	1990-2008	80 ⁹	≤ 21 (ISIC sections)
	219	all ¹	93 ¹⁰	Totals ¹⁶ only
Energy-steel production recipes	220	all ¹	all	Coal, oil, gas, iron ore, steel, electricity
Comtrade and Servicetrade	221	all ¹	all	All
GDP projections	222, 223	2021-2028	all	Totals ¹⁶ only
MRIO data	224	1995-2018	64 ¹¹	36
Household consumption	225	various ²	83 ¹²	61
Total output	201-204	1990-2019	164 ¹³	<238 (ISIC groups)
National Accounts Official Country data	200	1990-2017	128 ¹⁴	Mostly totals ¹⁶ only
Engineering exclusions	26	all	all	all
National IO databases	206	1990-2013	74 ¹⁵	varying

Note: Coverage information refers to maximum coverage. For example, maximum regional and/or sectoral coverage may not exist for all years.

¹ "all" under years means 1990-2021.

² 2007, 2008, 2009, 2008, 2010, 2010, 2003, 2007, 2007, 2007, 2008-09, 2003, 2009, 2006, 2007-08, 2007, 2007, 2003, NA, 2010, 2004, 2005, 2008, 1996, 2009, 1020, 2004, 2002, 2005, 2003, 2006, 2000, 2007, 2004, 2009, 2010, 2006, 2007, 2002, 2003, 2005, 2010, 2007, 2009, 2002, 2007, 2008, 2003, 2005, 2010-11, 2009-10, 2006, 2004, 2006-07, 2010, 2009, 2007-08, 2009, 2000, 2008, 2009, 2010, 2005, 2007, 2009, 2010, 2009, 2000, 2010, 2006, 2009, 2008, 2005, 2000, 2005, 2007, 2003, 2010-11, 2009, 2010, 2009, 2007, 2009, 2010, 2006, 2009, 2009, 2010, 2008, 2005, 2010

³ Remainder imputed by mean⁴Afghanistan, Angola, Albania, United Arab Emirates, Argentina, Armenia, Australia, Austria, Azerbaijan, Burundi, Belgium, Benin, Burkina Faso, Bangladesh, Bulgaria, Bahamas, Bosnia and Herzegovina, Belarus, Belize, Bolivia, Brazil, Brunei Darussalam, Botswana, Central African Republic, Canada, Switzerland, Chile, China, Cote d'Ivoire, Cameroon, DR Congo, Rep Congo, Colombia, Costa Rica, Cuba, Cyprus, CSSR/Czech Republic (1990-1991), Germany, Djibouti, Denmark, Dominican Republic, Algeria, Ecuador, Egypt, Spain, Estonia, Ethiopia/DR Ethiopia (1992/1993), Finland, France, Gabon, United Kingdom, Georgia, Ghana, Guinea, Gambia, Greece, Guatemala, Honduras, Hong Kong, Croatia, Haiti, Hungary, Indonesia, India, Ireland, Iran, Iraq, Iceland, Israel, Italy, Jamacia, Jordan, Japan, Kazakhstan, Kenya, Kyrgyzstan, Cambodia, South Korea, Kuwait, Laos, Lebanon, Liberia, Libya, Sri Lanka, Lithuania, Luxembourg, Latvia, Morocco, Moldova, Madagascar, Mexico, Macedonia, Mali, Malta, Myanmar, Mongolia, Mozambique, Mauritania, Malawi, Malaysia, Namibia, Niger, Nigeria, Nicaragua, Netherlands, Norway, Nepal, New Zealand, Oman, Pakistan, Panama,

Peru, Philippines, Papua New Guinea, Poland, North Korea, Portugal, Paraguay, Romania, USSR/Russian Federation (1990/1991), Rwanda, Saudi Arabia, Senegal, Sierra Leone, El Salvador, Yugoslavia/Serbia (1991/1992), Sudan/North Sudan (2010/2011), Slovakia, Slovenia, Sweden, Syria, Chad, Togo, Thailand, Tajikistan, Turkmenistan, Tunisia, Turkey, Tanzania, Uganda, Ukraine, Uruguay, United States of America, Uzbekistan, Venezuela, Viet Nam, Yemen Arab Republic/Yemen (1990/1991), South Africa, Zambia, Zimbabwe

⁵ Angola, United Arab Emirates, Argentina, Armenia, Australia, Austria, Azerbaijan, Burundi, Belgium, Benin, Burkina Faso, Bulgaria, Bahrain, Bahamas, Bosnia and Herzegovina, Belarus, Bolivia, Brazil, Brunei Darussalam, Bhutan, Botswana, Central African Republic, Canada, Switzerland, Chile, China, Cote d'Ivoire, Cameroon, DR Congo, Rep Congo, Colombia, Costa Rica, Cuba, Cyprus, CSSR/Czech Republic (1990/1991), Germany, Djibouti, Denmark, Dominican Republic, Algeria, Ecuador, Egypt, Spain, Estonia, Finland, France, Gabon, United Kingdom, Georgia, Ghana, Guinea, Greece, Guatemala, Honduras, Hong Kong, Croatia, Hungary, India, Ireland, Iran, Iraq, Iceland, Israel, Italy, Jamaica, Jordan, Japan, Kazakhstan, Kenya, Kyrgyzstan, South Korea, Kuwait, Laos, Lebanon, Sri Lanka, Lithuania, Luxembourg, Latvia, Morocco, Moldova, Mexico, Macedonia, Mali, Malta, Mongolia, Mozambique, Mauritania, Malaysia, Namibia, Niger, Nigeria, Nicaragua, Netherlands, Norway, New Zealand, Oman, Panama, Peru, Philippines, Papua New Guinea, Poland, Portugal, Paraguay, Qatar, Romania, USSR/Russian Federation (1990/1991), Saudi Arabia, Senegal, Singapore, Sierra Leone, Yugoslavia/Serbia (1991/1992), Sudan/North Sudan (2010/2011), Slovakia, Slovenia, Sweden, Chad, Thailand, Tajikistan, Tunisia, Turkey, Tanzania, Ukraine, Uruguay, United States of America, Venezuela, South Africa, Zambia, Zimbabwe.

⁶ Armenia, Austria, Azerbaijan, Bulgaria, Bahrain, Bosnia and Herzegovina, Belarus, Brazil, Botswana, Canada, China, Colombia, Costa Rica, Cuba, Cyprus, CSSR/Czech Republic (1990/1991), Dominican Republic, Egypt, Estonia, France, United Kingdom, Georgia, Ghana, Gambia, Guatemala, Honduras, Hong Kong, Croatia, Hungary, Indonesia, Israel, Italy, Kazakhstan, Kyrgyzstan, Sri Lanka, Lithuania, Latvia, Moldova, Madagascar, Mexico, Macedonia, Malta, Mongolia, Namibia, Nicaragua, Netherlands, Nepal, Palestine, Panama, Peru, Philippines, Poland, Paraguay, Qatar, Romania, USSR/Russian Federation (1990/1991), Singapore, El Salvador, Yugoslavia/Serbia (1991/1992), Slovakia, Slovenia, Sweden, Thailand, Tajikistan, Turkmenistan, Turkey, Ukraine, Uruguay, United States of America, Uzbekistan, Venezuela.

⁷ Austria, Bahrain, Botswana, Switzerland, Chile, China, Colombia, Costa Rica, Cyprus, CSSR/Czech Republic (1990/1991), Denmark, Egypt, Finland, France, United Kingdom, Guatemala, Hong Kong, Croatia, Hungary, Indonesia, India, Ireland, Jamaica, Jordan, Japan, Kazakhstan, Kenya, South Korea, Kuwait, Sri Lanka, Moldova, Mexico, Macedonia, Myanmar, Malaysia, Namibia, Nicaragua, Netherlands, Norway, Pakistan, Peru, Philippines, Portugal, Paraguay, Rwanda, Singapore, Syria, Tanzania, Uruguay, United States of America, South Africa, Zimbabwe.

⁸ Albania, United Arab Emirates, Argentina, Armenia, Australia, Austria, Azerbaijan, Belgium, Bangladesh, Bulgaria, Bahrain, Bahamas, Belize, Bolivia, Brazil, Brunei Darussalam, Bhutan, Botswana, Canada, Switzerland, Chile, China, Colombia, Costa Rica, Cyprus, CSSR/Czech Republic (1990/1991), Germany, Denmark, Dominican Republic, Algeria, Ecuador, Egypt, Spain, Estonia, Ethiopia/DR Ethiopia (1992/1993), Finland, France, United Kingdom, Georgia, Greece, Guatemala, Croatia, Hungary, Indonesia, Ireland, Iran, Iceland, Israel, Italy, Japan, Kazakhstan, Kyrgyzstan, Cambodia, South Korea, Kuwait, Sri Lanka, Lithuania, Luxembourg, Latvia, Morocco, Moldova, Madagascar, Mexico, Macedonia, Mali, Malta, Mongolia, Malaysia, Namibia, Nicaragua, Netherlands, Norway, Nepal, New Zealand, Oman, Palestine, Panama, Peru, Philippines, Papua New Guinea, Poland, Portugal, Paraguay, Qatar, Romania, USSR/Russian Federation (1990/1991), Saudi Arabia, Senegal, Singapore, Sierra Leone, El Salvador, Yugoslavia/Serbia (1991/1992), Slovakia, Slovenia, Sweden, Syria, Thailand, Tajikistan, Turkey, Tanzania, Uganda, Ukraine, Uruguay, United States of America, Viet Nam, Yemen Arab Republic/Yemen (1990/1991), South Africa

⁹ Angola, Argentina, Australia, Austria, Azerbaijan, Belgium, Bangladesh, Bulgaria, Belarus, Belize, Bolivia, Brazil, Brunei Darussalam, Canada, Switzerland, Chile, China, Colombia, Costa Rica, Cuba, Cyprus, CSSR/Czech Republic (1990/1991), Germany, Denmark, Dominican Republic, Algeria, Ecuador, Egypt, Spain, Ethiopia/DR Ethiopia (1992/1993), Finland, France, Gabon, United Kingdom, Greece, Guatemala, Honduras, Hong Kong, Haiti, Hungary, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, South Korea, Sri Lanka, Luxembourg, Morocco, Moldova, Mexico, Myanmar, Malaysia, Nicaragua, Netherlands, Norway, New Zealand, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Paraguay, Romania, USSR/Russian Federation (1990/1991), Singapore, El Salvador, Sweden, Syria, Thailand, Turkey, Ukraine, Uruguay, United States of America, Uzbekistan, Venezuela, Viet Nam, Zambia.

¹⁰ ILO: Afghanistan, Angola, Albania, United Arab Emirates, Armenia, Austria, Burundi, Belgium, Burkina Faso, Bangladesh, Bulgaria, Bosnia and Herzegovina, Belarus, Bolivia, Brazil, Brunei Darussalam, Bhutan, Botswana, Switzerland, Chile, Cote d'Ivoire, DR Congo, Rep Congo, Colombia, Costa Rica, Cyprus, CSSR/Czech Republic (1990/1991), Germany, Denmark, Dominican Republic, Ecuador, Egypt, Spain, Estonia, Ethiopia/DR Ethiopia (1992/1993), Finland, France, United Kingdom, Georgia, Ghana, Gambia, Greece, Guatemala, Honduras, Croatia, Hungary, Indonesia, India, Ireland, Iran, Iraq, Iceland, Israel, Italy, Jordan, Japan, Kenya, Kyrgyzstan, Cambodia, Laos, Lebanon, Liberia, Sri Lanka, Lithuania, Luxembourg, Latvia, Madagascar, Mexico, Macedonia, Mali, Malta, Myanmar, Mongolia, Mozambique, Mauritania, Namibia, Niger, Nigeria, Netherlands, Norway, Nepal, Pakistan, Palestine, Panama, Peru, Philippines, Poland, Portugal, Romania, Rwanda, Senegal, Singapore, Sierra Leone, El Salvador, Somalia, Yugoslavia/Serbia (1991/1992), Sudan/North Sudan (2010/2011), Slovakia, Slovenia, Sweden, Chad, Togo, Thailand, Tunisia, Turkey, Tanzania, Uganda, Uruguay, United States of America, Viet Nam, Zambia, Zimbabwe.

¹¹ OECD Countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel I, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, Mexico - Activities excluding Global Manufacturing, Mexico - Global Manufacturing activities. Non-OECD Economies: Argentina, Brazil, Brunei Darussalam, Bulgaria, Cambodia, China (People's Republic of), Colombia, Costa Rica, Croatia, Cyprus 2, India, Indonesia, Hong Kong, China, Kazakhstan, Malaysia, Malta, Morocco, Peru, Philippines, Romania, Russian Federation, Saudi Arabia, Singapore, South Africa, Chinese Taipei, Thailand, Tunisia, Viet Nam, Rest of the World, China - Activities excluding export processing, China - Export processing activities.

¹² Afghanistan, Albania, Armenia, Azerbaijan, Bangladesh, Belarus, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Cabo Verde, Chad, China, Colombia, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Djibouti, Egypt, Arab Rep., El Salvador, Ethiopia, Fiji, Gabon, Gambia, The, Ghana, Guatemala, Guinea, Honduras, India, Indonesia, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kyrgyz Republic, Lao PDR, Latvia, Lesotho, Liberia, Lithuania, Macedonia, FYR, Madagascar, Malawi, Maldives, Mali, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Nicaragua,

Niger, Nigeria, Pakistan, Papua New Guinea, Paraguay, Peru, Philippines, Romania, Russian Federation, Rwanda, Sao Tome and Principe, Senegal, Serbia, Sierra Leone, South Africa, Sri Lanka, Swaziland, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Turkey, Uganda, Ukraine, Vietnam, Yemen, Rep., Zambia.

¹³ *All GLORIA countries*

¹⁴ *Same as footnote 5.*

¹⁵ *Aruba, Netherlands Antilles, Argentina, Armenia, Australia, Austria, Belgium, Bolivia, Brazil, Canada, Switzerland, Chile, China, Colombia, Czech Republic, Germany, Denmark, Ecuador, Spain, Estonia, Finland, France, United Kingdom, Georgia, Greenland, Greece, Hong Kong, Hungary, Indonesia, India, Ireland, Iran, Israel, Italy, Japan, Kazakhstan, Kenya, Kyrgyzstan, Korea, Kuwait, Lithuania, Luxembourg, Latvia, Mauritania, Maldives, Mexico, Macedonia, Malta, Mongolia, Malaysia, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Paraguay, Romania, Russia, Singapore, Slovakia, Slovenia, Sweden, South Africa, Taiwan, Thailand, Turkey, Ukraine, Uruguay, Uzbekistan, Venezuela, Vietnam, United States of America.*

¹⁶ *“Totals” means national totals.*

5. Supplementary Discussion

Beyond national performance against SDG12, countries must be able to measure how their demand for goods and services influences environmental and social outcomes in their trading partners^{42,60}. The results produced by MRIO analysis can assist policy development so that SDG benefits to one country are not at the detriment to those of another⁴². For example, Malik, et al.⁴² find that 80% of the fatal and non-fatal accidents caused by the EU's consumption of textile products (such as clothing and leather products) are driven by just seven EU countries. Similarly, Xu, et al.²²⁶ find that international trade improved the SDG target scores of 65% of the evaluated developed countries but reduced the SDG target scores of over 60% of the evaluated developing countries. We show that, without careful consideration of embodied impacts, the consumption of one nation can influence SDG progress in other nations.

So, can national progress towards SDGs be measured without consideration of embodied impacts? If the answer is no, nations must incorporate measurements of how their consumption activities influence SDG progress elsewhere. For example, research has suggested that by offshoring production activities to cheaper developing countries, the environmental burdens in producing nations have increased²²⁷. This concept is heavily debated in emissions accounting, leading to questions about producer versus consumer responsibility²²⁸. MRIO analysis has enabled the knowledge around the need to consider trade activities, particularly in the context of consumer-responsibility.

Several regions are introducing legislation to monitor and reduce the impacts embodied in their supply chains²²⁹. For example, California was one of the first states to enact legislation addressing modern slavery in business supply chains²³⁰. The United Kingdom Modern Slavery Act (2015)²³¹ requires large businesses to report their efforts to ensure there is no slavery within their organisation and its supply chains²²⁹. In 2019, Australia's Modern Slavery Act came into force with similar stipulations for large businesses²³². Beyond Modern Slavery Acts, legislation specific to supply chains are being enacted. In 2023, Germany introduced a Supply Chain Act for ensuring due diligence obligations concerning human rights and environmental harms in their supply chain²³³. However, there are criticisms of the effectiveness of supply chain legislation in general. For example, many supply chain-related Acts have provisions that exempt small-medium enterprises (SMEs), which may have unsustainable supply chains²³⁴. However, legislation can spotlight these issues and indirectly incentivise other businesses to reduce their supply chain impacts. So, what does this mean for the SDGs of other countries? German policymakers could benefit from a tool that enables them to evaluate companies' supply chain due diligence to ensure that other nations' SDGs are not compromised.

The UN Statistical Commission will review the SDG indicators comprehensively at the fifty-sixth session in 2025. Indicators developed by the Member States will complement the global indicator framework at the regional and national levels²³⁵. With the Indicator review approaching, indicators must account for transboundary enablers and constraints that exist because of trade networks. MRIO analysis can support the measurement of these complex interactions to assist policy-makers in developing strategies to support other nations' SDG performance, for example fair trade practices.

Fair trade seeks greater equity in international trade and involves developmental and commercial activities, such as fair trade certifications, and advocacy campaigns linked to consumer action^{236,237}. The majority of fair trade is in the food sector, with coffee being the first and largest fair trade-certified commodity consumed globally²³⁸. Standard-setting organisations, like Fairtrade International, support farmers and their families to receive better than market prices for their goods²³⁹. For example, Majomut members, representing indigenous groups Tsotsil and Tzeltal in Chipas, Mexico²⁴⁰, selling their coffee

through fair trade cooperatives earn an average of US\$1700 per year, whereas, in the conventional market, their coffee would fetch only US\$550²³⁸. There are also additional social and environmental benefits of fair trade, such as strengthening community collectives, improving access to markets, and reducing poverty²³⁶. Fair trade is considered a sustainable course of action to meet the social needs of a community based on its environmental resources²³⁷. Beyond fair trade certifications, the World Trade Organisation (WTO), the international body governing global trade, can foster international cooperation regarding issues such as food security¹⁸⁸. Consumer awareness and purchasing power can foster greater support for fair trade practices^{236,237}.

In addition to the effects of international trade as studied in this work, SDG progress can be influenced by many intersecting and compounding factors, including power distributions across global value chains (GVC)¹²⁻¹⁴, social or political polarization¹⁵ (the division of society into groups based on race, religion, and/or politics¹⁶), geopolitical conflict¹⁷ and disasters¹⁵.

GVC research explains how market access depends on participation in global production networks led by firms based in developed countries¹³. The dominance of a country in global trade is closely tied to the fragmentation of production across international borders, leading to complex structures within global value chains¹². Since the 1970s, US branded manufacturers emphasized higher profit-earning activities such as marketing and design over production and moving production to the Global South where wages and prices were lower¹³. Wage inequalities hinge on productivity differences, i.e., Global North exports embody higher labour productivity, so they have a greater value-added²⁴¹. Value-adding activities include research, design, production, logistics, marketing, and service, which drive value for the final good or service²⁴². For example, 90% of tea GVCs are controlled by seven multinationals, which dominate the value-added logistics and marketing activities in the value chain²⁴³. Such institutional power structures, which control the most profitable value-added activities (packing and marketing), prevent Global South economies from benefiting from access to international trade markets¹⁴.

Political and social polarization can lead to equally polarising perspectives on issues like climate change^{244,245}. A global study suggests that income equality and political polarization are significantly positively correlated⁶⁵. Over time, rising income inequality is likely to increase political inequality²⁴⁶. Research also suggests that social polarization and income inequality are positively linked, resulting in broader societal impacts on sustainable development progress. For example, the positive relationship between social polarisation and income inequality in Chile can create and intensify existing social discontent stemming from conflicts and social injustices²⁴⁷.

Geopolitical conflicts like the Russia-Ukraine War can also impact SDG progress¹⁷, especially for SDG2 (Zero Hunger) indicators such as food security, hunger and undernourishment²⁴⁸. The Middle East and African regions dependent on Ukraine's wheat imports are particularly affected²⁴⁹. Global crises and national disasters, such as COVID-19, can stall SDG progress globally, albeit with significant regional differences. Globally, the COVID-19 pandemic most impacted global progress towards poverty reduction (SDG 1), decent work and economic growth (SDG8) and reduced inequality (SDG 10), with the greatest regional impacts felt in the Global South, particularly African countries⁵⁴.

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