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Environmental and social footprints of international trade

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Supplementary Information

Supplementary Table 1 | Recent studies quantifying impacts embodied in global trade (update of Table 8.1 in Wiedmann, 2016).
The focus is on global *multi-region input-output (GMRIO) analyses* over the last five years with some exceptions of salient publications using different approaches, focusing on specific indicators or regions or from earlier years (n.p. = not provided).

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
Air pollution – Acid emissions (NH_3, NO_x, SO_x)	**26%** (2.1 Mt H^+e, 2008)	i) China (0.65 Mt H^+e) ii) USA (0.35 Mt H^+e)	GMRIO analysis (WIOD)	Arto et al., 2012
Air pollution – Acid emissions (SO_2, NO_x)	n.p.	n.p.	GMRIO analysis (Eora)	Kanemoto et al., 2014
Air pollution – Aerosols – Climatic effects	n.p.	n.p.	GMRIO analysis (GTAP)	Lin et al., 2016
Air pollution – Ozone precursors (NMVOC, CH_4, CO, NO_x)	**28%** (109 Mt NMVOCe, 2008)	i) China (17.4 Mt NMVOCe) ii) USA (18.6 Mt NMVOCe)	GMRIO analysis (WIOD)	Arto et al., 2012
Air pollution – PM_{10} – Health impacts	n.p.	i) China (net) ii) USA (net)	GMRIO analysis (Eora)	Xiao et al., 2018b

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
Air pollution – $PM_{2.5}$	**30%** (7.2 Tg of 24 Tg primary emissions, 2007)	i) China	GMRIO analysis (GTAP)	Meng et al., 2016
Air pollution – $PM_{2.5}$ – Premature deaths	**22%** (762,400 of 3.45 million premature deaths related to $PM_{2.5}$ emissions, 2007)	n.p.	GMRIO analysis (GTAP)	Zhang et al., 2017a
Air pollution – $PM_{2.5}$ – Health impacts	**26%** (1.1 of 4.1 million DALY, 2010)	n.p.	GMRIO analysis (Eora)	Liang et al., 2017b
Biodiversity	**25%** (228 of 927 projected global extinctions of endemic species, 2017)	i) Indonesia ii) USA	GMRIO analysis (GTAP)	Chaudhary and Brooks,
Biodiversity	**17%** (species 'committed to extinction' in international trade of crops, 2012)	n.p.	Biophysical trade analysis (FAOSTAT)	Chaudhary and Kastner, 2016
Biodiversity	(ecosystem services worth $1.5trillion/year embodied in timber trade, 2012)	n.p.	Biophysical trade analysis (FAOSTAT)	Chaudhary et al., 2017
Biodiversity	**30%** (species threats, 2009)	i) Indonesia (238 species threats) ii) USA (1262)	GMRIO analysis (Eora)	Lenzen et al., 2012
Biodiversity	n.p.	n.p.	GMRIO analysis (Eora)	Moran and Kanemoto, 2017
Biodiversity	n.p.	n.p.	GMRIO analysis (Eora)	Verones et al., 2017
Biodiversity	n.p.	n.p.	GMRIO analysis (WIOD)	Wilting et al., 2017
Carbon in products	**37%** (2.7 GtC as chemical element present in fossil fuels, 2004. Note: based on physical, not 'embodied' trade flows)	n.p.	Physical trade analysis	Peters et al., 2012
CO_2 emissions	n.p. (6.9 $GtCO_2$, 2007)	n.p.	GMRIO analysis (GTAP)	Andrew et al., 2013
CO_2 emissions	n.p.	i) Greater China (2.3 Gt CO_2, 2004) ii) Western Europe (3.6 Gt CO_2, 2004)	Global Interregional Social Accounting Matrix (GTAP)	Bergmann, 2013
CO_2 emissions	**23%** (6.2 Gt CO_2, 2004)	i) China (1.43 Gt CO_2) ii) USA (1.22 Gt CO_2)	GMRIO analysis (GTAP)	Davis and Caldeira, 2010

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
CO_2 emissions	**23%** (6.4 Gt CO_2, 2004)	i) China (1.24 Gt CO_2, 2004), ii) USA (1.22 Gt CO_2)	GMRIO analysis (GTAP)	Davis et al., 2011
CO_2 emissions	n.p.	i) China ii) USA	GMRIO analysis (WIOD)	de Vries and Ferrarini, 2017
CO_2 emissions	**25%** (6.2 Gt of 24.9 Gt CO_2, 2009)	i) China ii) USA	GMRIO analysis (WIOD)	Fan et al., 2017
CO_2 emissions	n.p.	n.p.	GMRIO analysis (OECD)	Jiang and Guan, 2017
CO_2 emissions	n.p.	n.p.	GMRIO analysis (WIOD)	Kagawa et al., 2015
CO_2 emissions	n.p.	n.p.	GMRIO analysis (Eora)	Kanemoto et al., 2014
CO_2 emissions	**23.5%** (5.8 Gt CO_2, 2009)	n.p.	GMRIO analysis (WIOD, seven regions)	López et al., 2018
CO_2 emissions	n.p.	n.p.	GMRIO analysis (Eora)	Malik and Lan, 2016
CO_2 emissions	n.p.	i) China	Single-region IO analysis (China SRIOT)	Pan et al., 2017
CO_2 emissions	**26%** (7.8 Gt CO_2 in 2008)	n.p.	GMRIO analysis (GTAP)	Peters et al., 2011
CO_2 emissions	**22%** (1.7 Gt C = 6.1 Gt CO_2, 2004),	n.p.	Synthesis of GMRIO-based studies	Peters et al., 2012
CO_2 emissions	n.p.	n.p.	GMRIO analysis (Eora)	Prell and Feng, 2016a, b
CO_2 emissions	**25%** (7.5 Gt CO_2, 2006)	n.p.	Physical trade analysis with life cycle inventory factors for carbon intensity of products	Sato, 2014
CO_2 emissions	n.p. (OECD countries only)	i) China ii) USA	GMRIO analysis (OECD ICIO)	Wiebe and Yamano, 2016
CO_2 emissions	**33%** (8.3 Gt CO_2, 2007)	n.p.	GMRIO analysis (WIOD)	Xu and Dietzenbacher, 2014

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
CO_2 emissions	**25%** ("**8%** of global CO_2 emissions are related to trade in final products, **11%** corresponds to trade in intermediate goods for the last stage of production, and **6%** is caused by the global value chain related trade", p.16, 2009)	i) China ii) USA	GMRIO analysis (WIOD)	Zhang et al., 2017b
CO_2 emissions	**20%** (5.1 Gt of 25 Gt CO_2, 2011)	i) China ii) USA (country), EU (region)	GMRIO analysis (GTAP)	Zhu et al., 2018
CO_2 emissions – climatic effects	n.p.	n.p.	n.p.	Wei et al., 2016
CO_2 emissions from traded fossil fuels	n.p. (10.8 Gt CO_2, 2007)	n.p.	GMRIO analysis (GTAP)	Andrew et al., 2013
CO_2 emissions from traded fossil fuels	**37%** (10.2 Gt CO_2, 2004)	i) Russia (1.47 Gt CO_2, 2004) ii) USA (2.08 Gt CO_2)	GMRIO analysis (GTAP)	Davis et al., 2011
Economic output	**23%** (49 of 211 trillion US$ global economic output, 2010)	n.p.	GMRIO analysis (Eora)	Liang et al., 2017b
Energy	n.p.	n.p.	GMRIO analysis (WIOD)	Arto et al., 2016b
Energy	**33%** (1.78E+08 TJ of 5.32E+08 TJ, 2010)	i) Russia ii) USA	GMRIO analysis (Eora)	Chen and Wu, 2017
Energy	n.p.	n.p.	GMRIO analysis (Eora)	Chen et al., 2018b
Energy	n.p.	i) China (net) ii) USA (net)	GMRIO analysis (GTAP)	Gasim, 2015
Energy	n.p.	n.p.	GMRIO analysis (Eora)	Lan et al., 2016
Energy	**35%** (n.p., 2007)	i) Russia (23 PJ) ii) USA (25 PJ)	GMRIO analysis (EXIOBASE)	Simas et al., 2015
Energy	**29%** (n.p., 2011)	n.p.	GMRIO analysis (EXIOBASE)	Wood et al.,
Energy	n.p.	i) China (net) ii) USA (net) (for final consumption)	GMRIO analysis (Eora)	Wu and Chen, 2017
GHG emissions	**27%** (10.4 Gt CO_2e, 2008)	i) China (2.9 Gt CO_2e) ii) USA (1.8 Gt CO_2e)	GMRIO analysis (WIOD)	Arto et al., 2012

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
GHG emissions	n.p.	i) China ii) USA	GMRIO analysis (GTAP)	Fernández-Amador et al., 2016
GHG emissions	n.p.	n.p.	GMRIO analysis (WIOD)	Liang et al., 2017a
GHG emissions	**23%** (8.7 Gt CO_2e, 2007)	n.p.	GMRIO analysis (EXIOBASE)	Tukker et al., 2014
GHG emissions	**24%** (n.p., 2011)	n.p.	GMRIO analysis (EXIOBASE)	Wood et al.,
HANPP (human appropriation of net primary production)	n.p. (EU only)	n.p.	Biophysical trade analysis (FAOSTAT)	Kastner et al., 2015
Income – Inequality	n.p.	n.p.	GMRIO analysis (Eora)	Alsamawi et al., 2014b
Income – Wages	n.p.	n.p.	GMRIO analysis (Eora)	Alsamawi et al., 2014a
Income – Wages	n.p.	n.p.	GMRIO analysis (Eora)	Reyes et al., 2017
Labour	**18%** (560 million persons-year equivalents, 2007)	i) China (130 mpeq) ii) USA (115 mpeq)	GMRIO analysis (EXIOBASE)	Simas et al., 2015
Labour – Low-skilled labour, Forced labour, Occupational health damage, Child labour, Vulnerable employment, Hazardous child labour, Labour by women	**16%** for total labour, **15%** for low-skilled labour, **17%** for forced labour, **18%** for occupational health damage, **19%** for child labour, **19%** for vulnerable employment, **20%** for hazardous child labour, and **38%** for labour by women (all numbers for trade between seven world regions)	i) The APAC region is the largest exporter of all forms of (bad) labour, except for child labour and hazardous child labour for which Africa is the largest exporter ii) n.p.	GMRIO analysis (EXIOBASE)	Simas et al., 2014
Labour – Child labour	n.p. (India only)	n.p.	GMRIO analysis (Eora)	Gómez-Paredes et al., 2016
Labour – Employment	n.p.	n.p.	GMRIO analysis (WIOD)	Portella-Carbó, 2016
Labour – employment Income – wages	n.p.	n.p.	GMRIO analysis (Eora)	Reyes et al., 2017

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
Labour – Employment, Working hours, Wages, Occupational accidents, Unemployment	n.p.	n.p.	GMRIO analysis (EXIOBASE)	Hardadi and Pizzol, 2017
Land	**23%** (1660 Mha, 2008)	i) China (160 Mha) ii) USA (260 Mha)	GMRIO analysis (WIOD)	Arto et al., 2012
Land	n.p.	n.p.	Review of studies based on GMRIO, biophysical trade and hybrid analysis	Bruckner et al., 2015
Land	**33%** (2010)	i) USA ii) USA	GMRIO analysis (Eora)	Chen and Han, 2015
Land	**21%** (272 of 1321 Mhayr^{-1}, 2008)	i) USA ii) China (GMRIO analysis suggests that China is a major exporter, see Kastner et al., 2014b)	Biophysical trade analysis (FAOSTAT)	Kastner et al., 2014a
Land	n.p. (land use change related to Nickel consumption)	n.p.	GMRIO analysis (GLIO)	Nakajima et al.,
Land	n.p.	n.p.	Review of studies based on GMRIO, biophysical trade and hybrid analysis	Schaffartzik et al., 2015
Land	**24%** (1800 Mgha biologically productive land area, 2004)	i) China (218 Mgha) ii) USA (326 Mgha)	GMRIO analysis (GTAP)	Weinzettel et al., 2013
Land	**26%** (n.p., 2011)	n.p.	GMRIO analysis (EXIOBASE)	Wood et al.,
Land	**27%** (2007)	i) Russia (258 Mha) ii) USA (198 Mha)	GMRIO analysis (GTAP)	Yu et al., 2013
Land – scarcity weighted	n.p.	n.p.	GMRIO analysis (EXIOBASE)	Font Vivanco et al., 2017a
Land – Undernourishment	n.p.	n.p.	GMRIO analysis (GTAP)	Marselis et al., 2017
Materials – Coal	**70%** (of total global coal extraction)	i) China ii) USA	GMRIO analysis (Eora)	Wu and Chen, 2018
Materials – Coal	**65%** (of total global coal direct supply, 2011)	i) China ii) USA	GMRIO analysis (Eora)	Xia et al., 2017

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
Materials – Metal ores	**62 % for iron ore** (1,380 Mt, 2008) **64 % for bauxite** (136 Mt, 2008)	i) Brazil (315 Mt iron ore), Australia (44 Mt bauxite) ii) China (350 Mt iron ore), USA (24 Mt bauxite)	GMRIO analysis (Eora)	Wiedmann et al., 2015a
Materials – Metal ores	n.p.	n.p.	GMRIO analysis (EXIOBASE)	Zheng et al., 2018
Materials – Metal ores (Coltan)	n.p. (Coltan = columbite-tantalite ore, see also Bleischwitz et al., 2012)	n.p.	GMRIO analysis (Eora)	Moran et al., 2015
Materials – Metal ores, scarcity weighted	n.p.	n.p.	GMRIO analysis (EXIOBASE)	Font Vivanco et al., 2017a
Materials – Raw materials	**24%** (16 Gt, 2008)	i) China (2.6 Gt) ii) USA (2.8 Gt)	GMRIO analysis (WIOD)	Arto et al., 2012
Materials – Raw materials	**26%** (15 Gt, 2005)	n.p. for countries i) OECD LD (5.5 Gt) ii) OECD HD (9.9. Gt)	IO table and physical trade analysis (GRAM/OECD)	Bruckner et al., 2012
Materials – Raw materials	n.p. (41 Gt, 2005)	n.p.	Physical trade analysis	Dittrich et al., 2012
Materials – Raw materials	**34%** (22 Gt, 2007)	i) China (3.9 Gt) ii) USA (3.5 Gt)	GMRIO analysis (GTAP)	Giljum et al., 2015
Materials – Raw materials	n.p. (EU-28 only)	n.p.	GMRIO analysis (EXIOBASE)	Giljum et al., 2016
Materials – Raw materials	n.p.	n.p.	GMRIO analysis (Eora)	Plank et al., 2018
Materials – Raw materials	n.p.	n.p.	Summary of studies based on GMRIO and physical trade analysis	UNEP, 2015

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
Materials – Raw materials	**41%** (29 Gt, 2008)	i) India (0.5 Gt biomass) China (5.2 Gt construction materials) Russia (1.2 Gt fossil fuels) Chile (0.7 Gt metal ores) ii) USA (0.8 Gt biomass) USA (2.1 Gt construction materials) USA (1.3 Gt fossil fuels) USA (0.7 Gt metal ores)	GMRIO analysis (Eora)	Wiedmann et al., 2015b
Materials – Raw materials	**32%** (n.p., 2011)	n.p.	GMRIO analysis (EXIOBASE)	Wood et al.,
Metals – Mercury	**30%** (253 of 859 t total global mercury emissions from fossil fuel combustion, 2010).	i) China ii) USA	GMRIO analysis (Eora)	Chen et al., 2016
Metals – Mercury	**67%** (674 t of 974 t of global mercury emissions from non-ferrous metal production)	n.p.	GMRIO analysis (Eora)	Li et al., 2017
Multiple indicators: Air pollution – PM_{10}, Biodiversity CO_2 emissions, Ecological Footprint, HANPP, Raw materials, Scarce water, Water	n.p.	n.p.	GMRIO analysis (Eora)	Moran et al., 2013
Multiple indicators: Ecological footprint, GHG emissions, Land, Raw materials, Waste, Water	n.p.	n.p.	GMRIO analysis (EXIOBASE)	Simas et al., 2017
Nexus: Air pollution (SO_2) + CO_2 emissions + Water	n.p. (electricity and chemicals sectors only, 1995-2009)	n.p.	GMRIO analysis (WIOD)	Acquaye et al., 2017

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
Nexus: Land + Water	**37%** of agricultural land, **29%** of agricultural freshwater (2012)	n.p.	GMRIO analysis (Eora)	Chen et al., 2018a
Nexus: Water + Energy	n.p.	n.p.	GMRIO analysis (GTAP)	Holland et al., 2015
Nexus: Water, Energy, Land, Metal ores, and Minerals	n.p.	n.p.	GMRIO analysis (EXIOBASE)	Font Vivanco et al.,
Nitrogen	**26%** (41.8 Tg of total industrial and agricultural emissions, separately: **25%** for Nwp **26%** for NH_3 **28%** for NO_x **27%** for N_2O)	i) China (net) ii) Japan (net)	GMRIO analysis (Eora)	Oita et al., 2016
Nitrogen	n.p.	n.p.	Physical trade analysis	Shibata et al., 2017
Phosphorus	n.p. (USA only)	n.p.	Biophysical trade analysis (USDA, FAOSTAT)	MacDonald et al., 2012
Phosphorus	n.p. (European P fertiliser footprint only)	n.p.	Physical trade analysis (FAOSTAT)	Nesme et al., 2016
Social risk – Occupational Health and Safety	n.p. ("12 fatal and 4.8 thousand non-fatal incidents, 27 thousand days lost and two million US$ lost in wages per 100 thousand workers in supply chains worldwide", 2010)	i) Nepal ii) Hong Kong (embodied fatalites)	GMRIO analysis (Eora)	Alsamawi et al., 2017
Social risk – Collective bargaining, Forced labour, Child labour, Gender equality, Hazardous work, Social security	n.p.	n.p.	GMRIO analysis (Eora)	Gómez-Paredes et al., 2015
Social risk – Corruption	n.p.	i) Madgaskar ii) Hong Kong	GMRIO analysis (Eora)	Xiao et al., 2018a
Social risk – Gender equality, Mother and child health, Governance, Access to clean water	n.p.	n.p.	GMRIO analysis (Eora)	Xiao et al., 2017

Impact	Fraction of total global impact embodied in trade (absolute amount, year)	Largest exporter (i), largest importer (ii), (gross trade flows of embodied impacts)	Method (name of database)	Reference
Waste – solid waste	n.p.	n.p.	GMRIO analysis (EXIOBASE)	Tisserant et al., 2017
Water	**22%** (2651 Gm³, 2008)	i) China (472 Gm³) ii) USA (427 Gm³)	GMRIO analysis (WIOD)	Arto et al., 2012
Water	n.p.	i) China ii) EU-27	GMRIO analysis (WIOD)	Arto et al., 2016a
Water	**30%** (2004)	i) China (204 Gm³) ii) USA (178 Gm³)	GMRIO analysis (GTAP)	Chen and Chen, 2013
Water	n.p.	n.p.	Biophysical trade analysis of virtual water related to agricultural products (FAOSTAT)	Dalin et al., 2012
Water	**26%** (2,320 Gm³, 1996–2005)	i) USA (314 Gm³/y) ii) USA (234 Gm³/y)	Water Footprint Network method (Hoekstra et al., 2011)	Hoekstra and Mekonnen, 2012;
Water	n.p.	n.p.	Biophysical trade analysis of virtual water related to food products (FAOSTAT)	Konar et al., 2011.
Water	**24%** (1900 Gm³, 2000)	i) USA (180 Gm³), ii) USA (300 Gm³)	GMRIO analysis (Eora)	Lenzen et al., 2013
Water	n.p. (EU-27 only)	n.p.	GMRIO analysis (EXIOBASE)	Lutter et al., 2016
Water	**ca. 10%** (blue + green)	n.p.	GMRIO analysis (GTAP)	Wang et al., 2016
Water	**26%** (n.p., 2011)	n.p.	GMRIO analysis (EXIOBASE)	Wood et al.,
Water - groundwater	**11%** (of global non-renewable groundwater use for irrigation embedded in international **food** trade; 18% of global crop production is traded internationally) 2010	In 2010, three countries alone – Pakistan, USA and India – exported 67% of trade-embodied groundwater (17.2 km³/yr).	Biophysical trade analysis of food products	Dalin et al., 2017
Water – pollution / grey water	**13%** (1677 of 13228 Gt, average 1995-2009)	n.p.	GMRIO analysis (WIOD)	Wan et al., 2016
Water – scarce water	**32%** (of global scarce water use, 480 Gm³, 2000)	i) India (30 Gm³), ii) USA (45 Gm³)	GMRIO analysis (Eora)	Lenzen et al., 2013

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