Environmental and social footprints of international trade

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Associate Professor of Sustainability Research
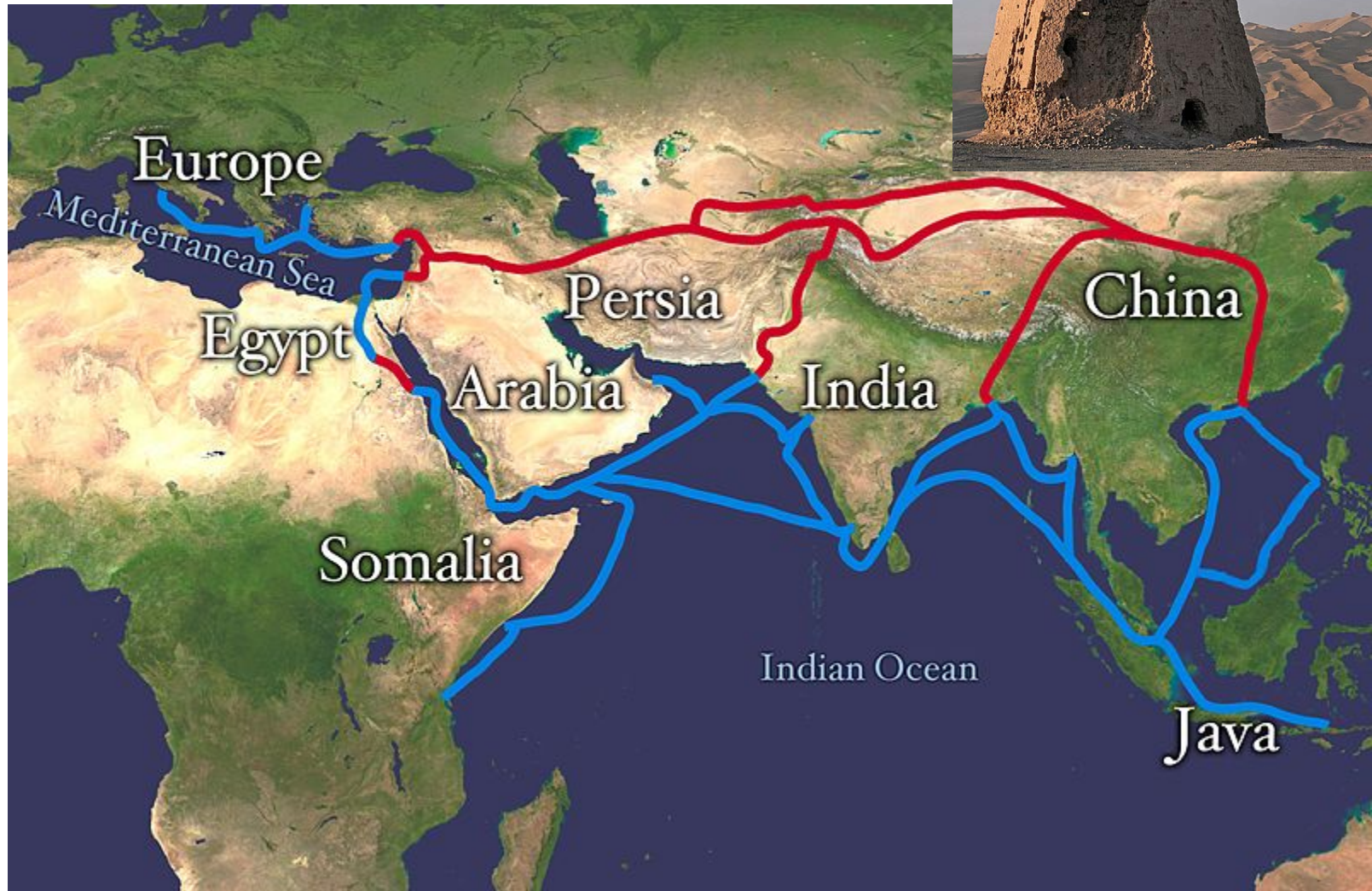
School of Civil and Environmental Engineering
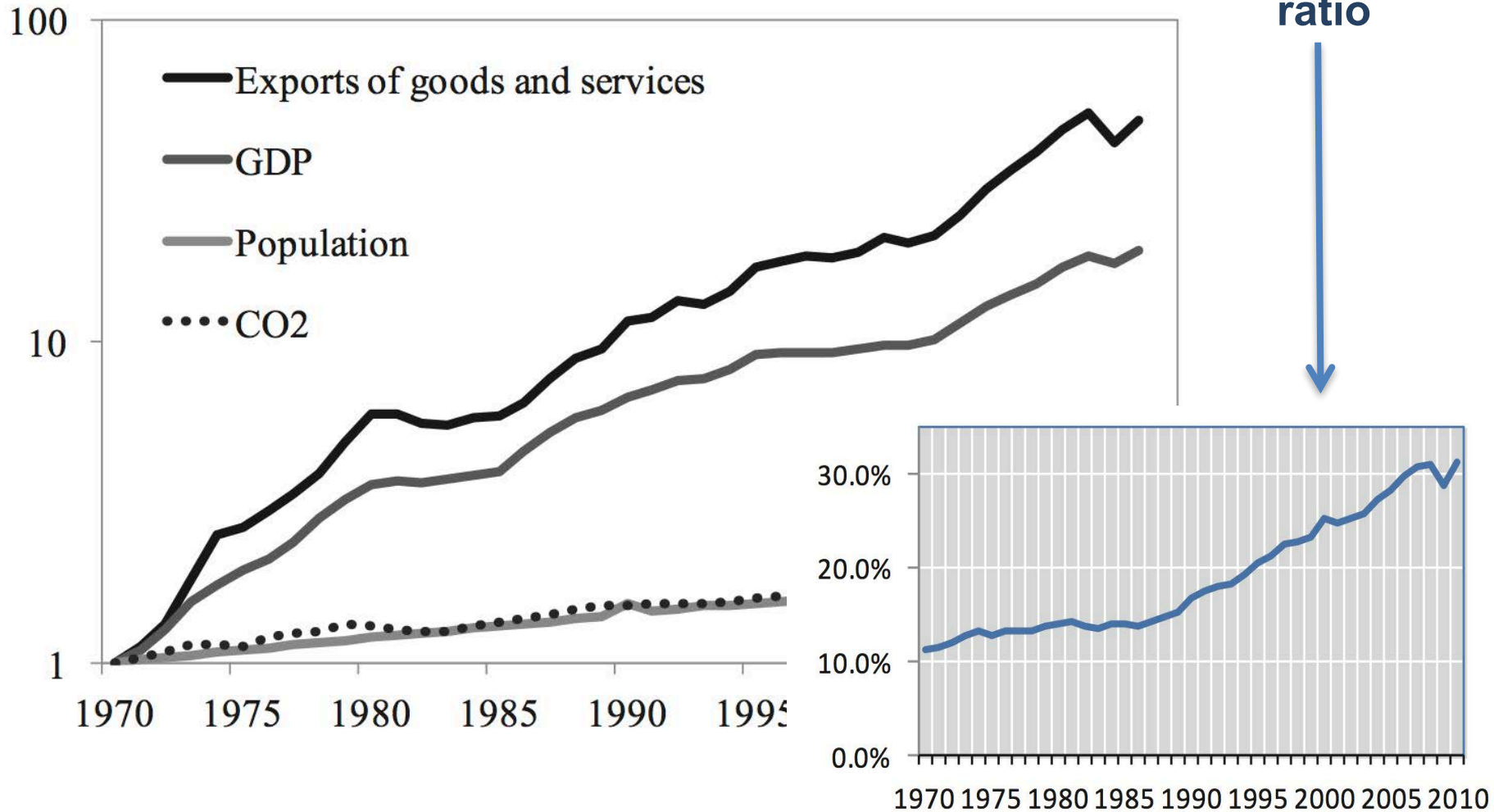UNSW Sydney, NSW 2052, Australia

http://www.sustainabilityresearch.unsw.edu.au

The Silk Road

Han Dynasty
206 BC - 220 AD

What's different in modern times?

Growth

World Export-to-GDP ratio

Scale

Complexity and Fragmentation

Complexity and Fragmentation

World – Merchandise Exports
Per cent of GDP, current prices

Intermediate

Final

Sources: IMF; OECD

Kelly & La Cava (2013) Value-added Trade (TiVA) and the Australian Economy. *Reserve Bank of Australia Bulletin*.
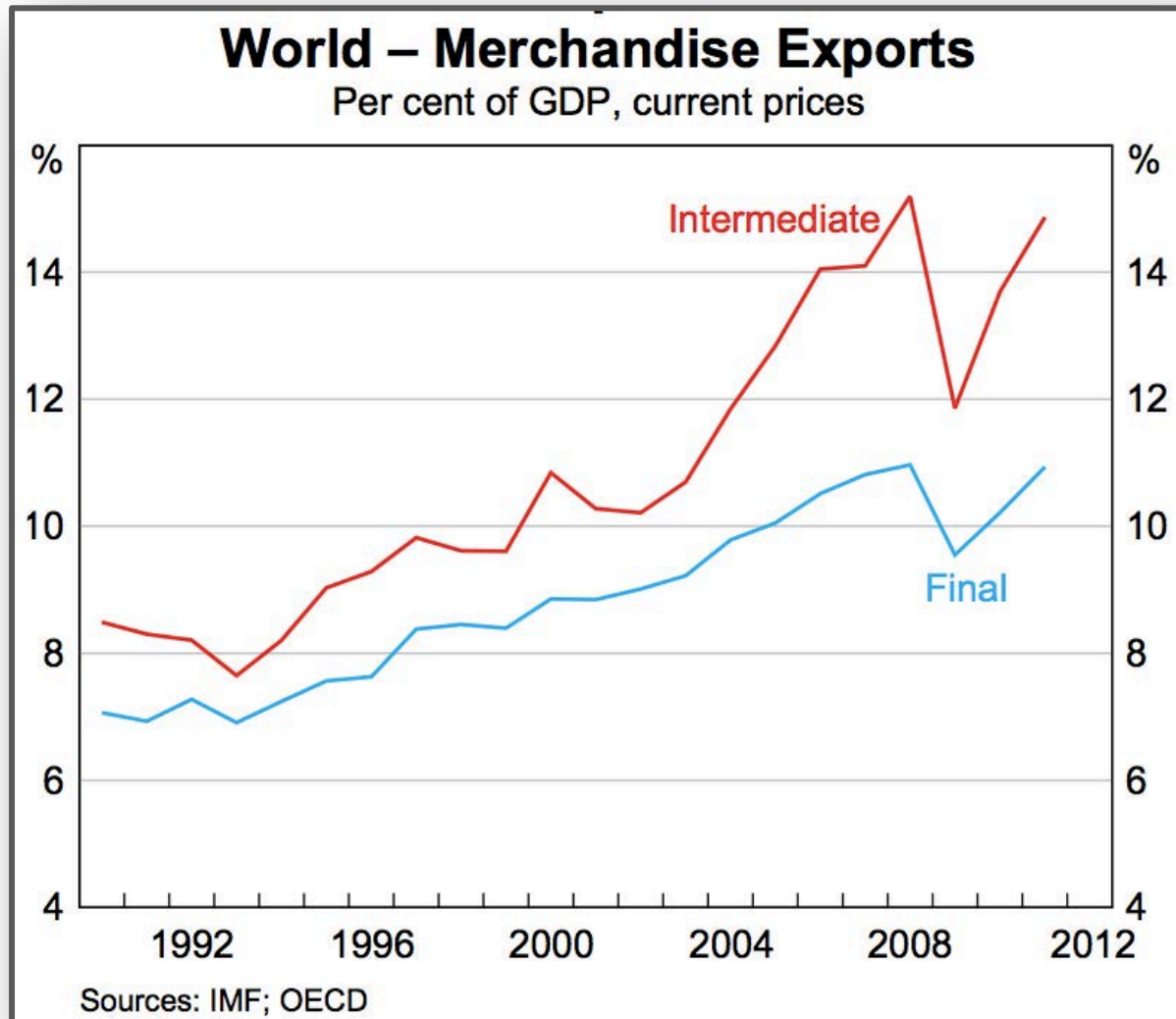
Average border-crossing frequencies of carbon footprints
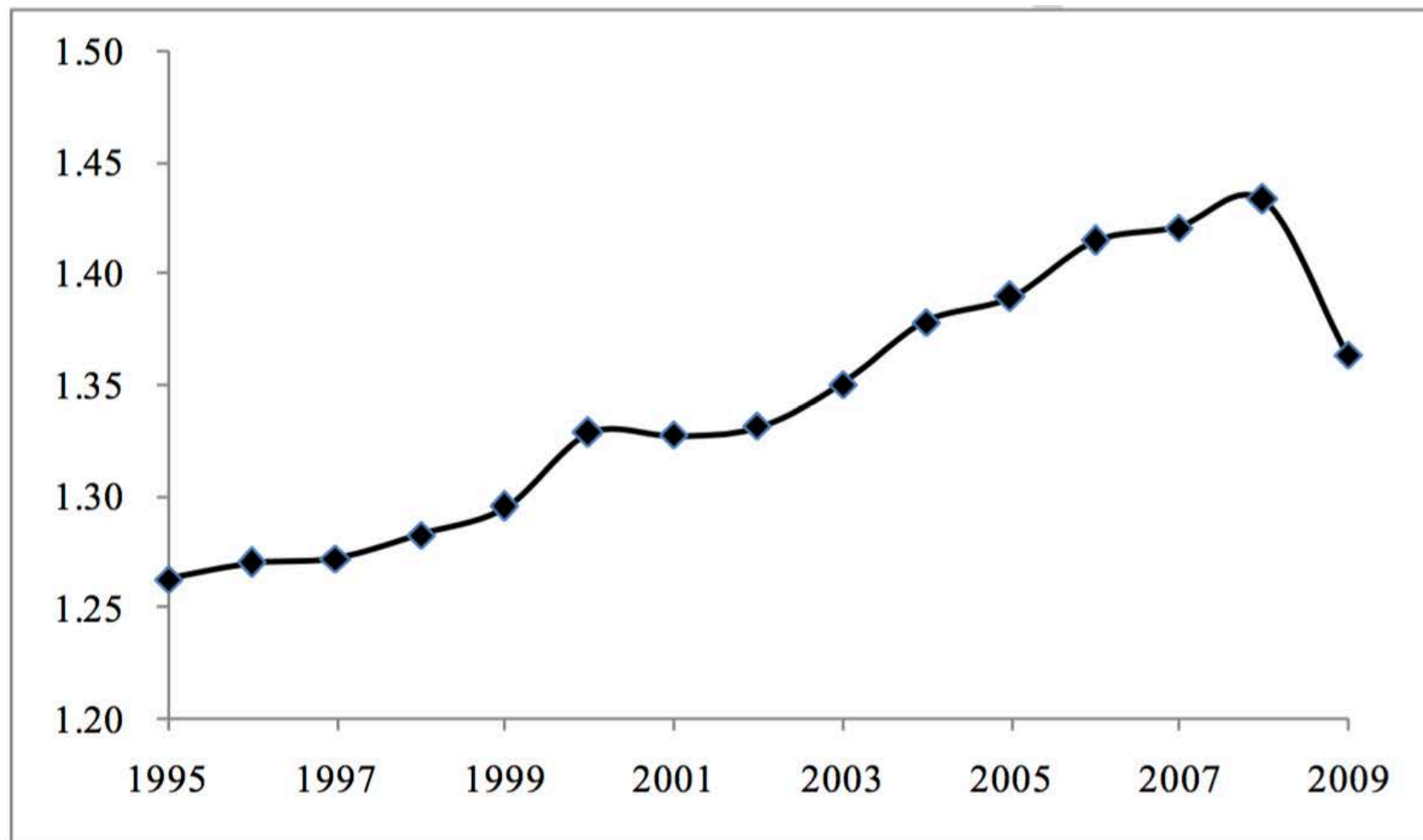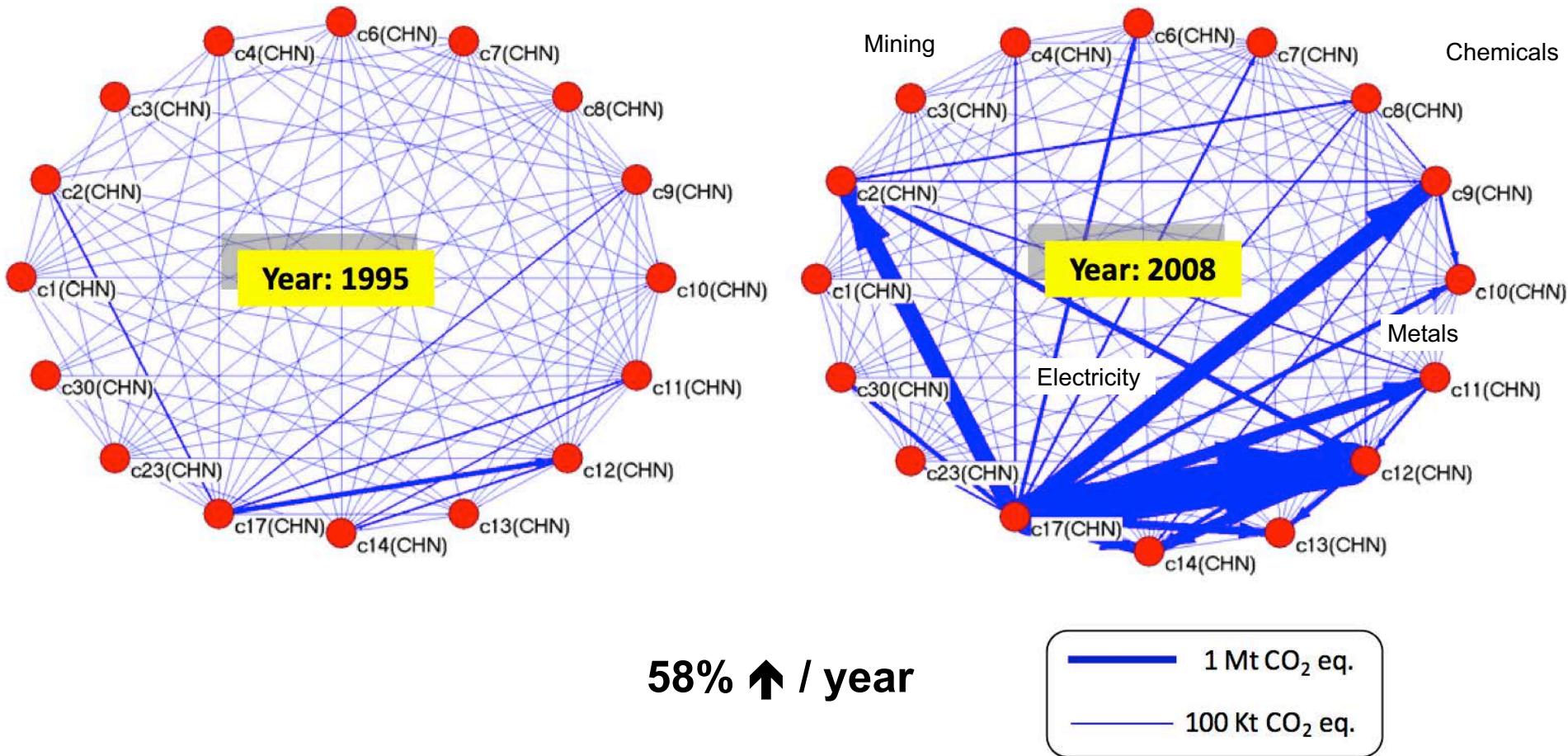
Interconnectivity

GHG emissions cluster in China induced by US demand in construction

58% ↑ / year

Kagawa S, Suh S, Hubacek K et al (2015) CO2 emission clusters within global supply chain networks: Implications for climate change mitigation. *Global Environmental Change*, **35**, 486-496. http://dx.doi.org/10.1016/j.gloenvcha.2015.04.003

Burden shifting

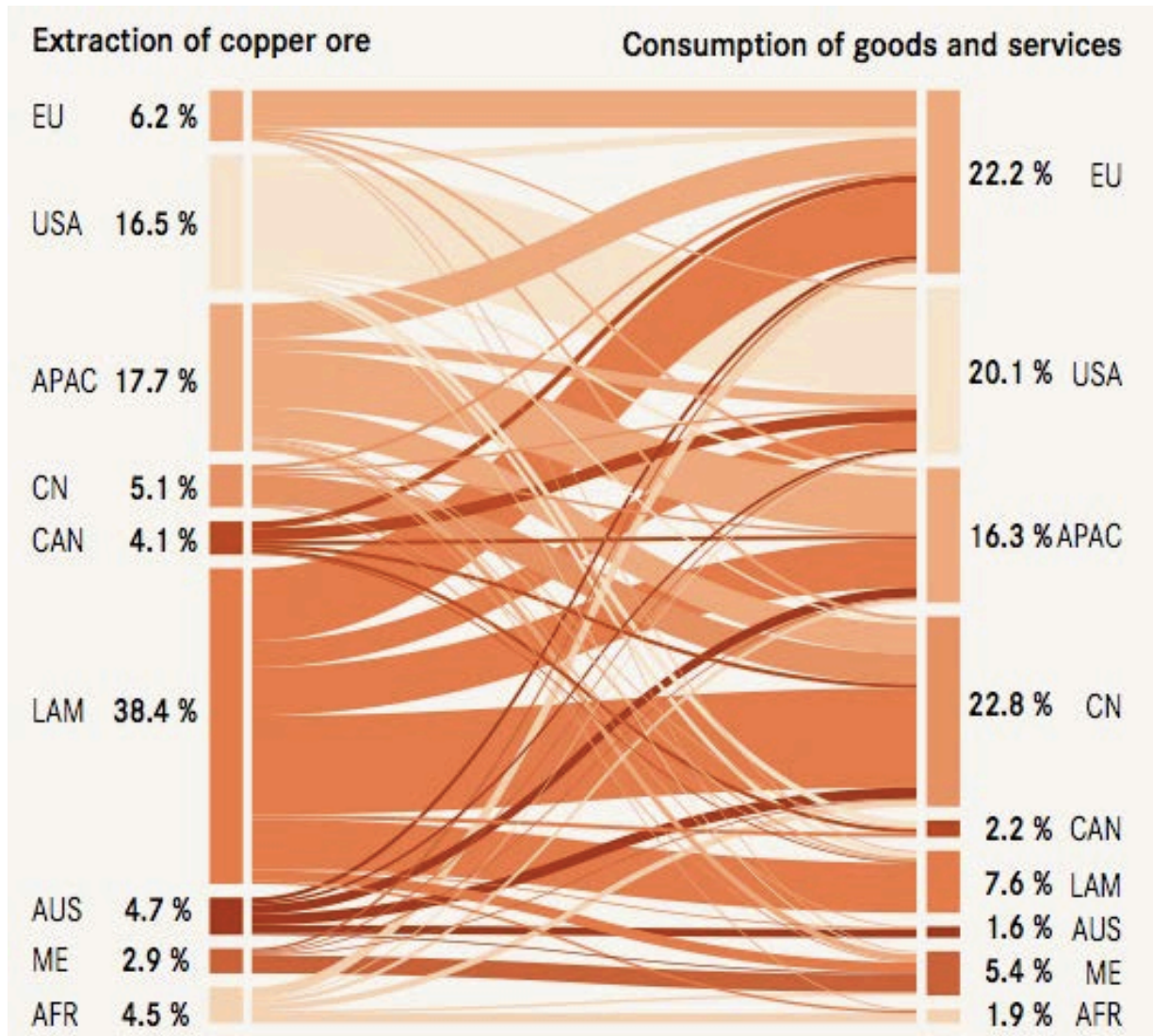# Consumption-based accounting for countries

territorial impacts

+ impacts embodied in **imports**
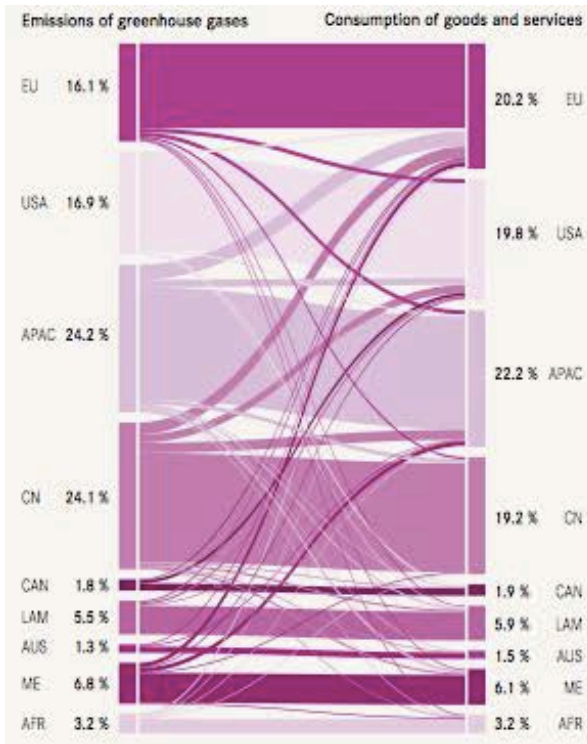
− impacts embodied in **exports**

= national **footprint**

How production and consumption are linked

How production and consumption are linked
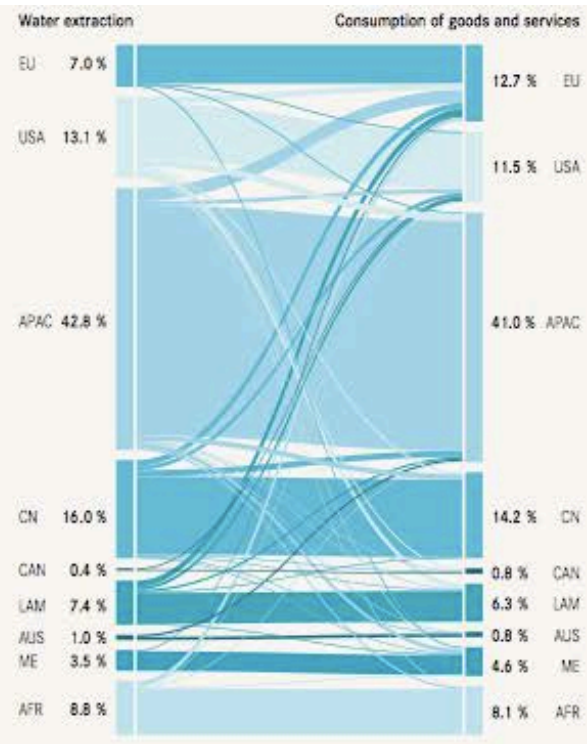
GHGs   Water   Land
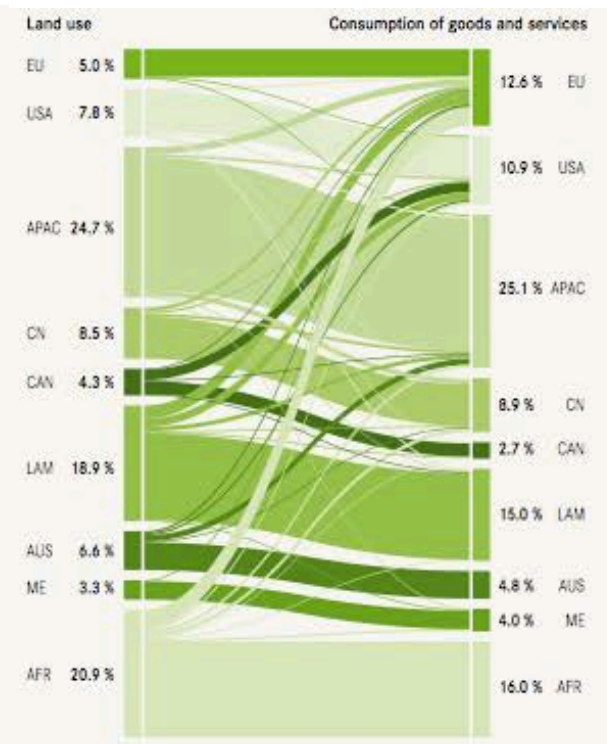
Burden shifting

10-30% of global surface and rainwater use

11% of global groundwater use

13% of global polluted water

15-38% of global labor

17-30% of global biodiversity loss

20-24% of global land use

22% of global $PM_{2.5}$-related deaths

22-30% of global air pollution

22-33% of global CO_2 emissions

23-30% of global GHG emissions

24-68% of global raw material extractions

26% of global reactive nitrogen emissions

32% of global scarce water use

35% of global energy use

62-64% of global metal ore extractions

67% of global mercury emissions

are embodied in international trade

GMRIO-calculated footprints of…
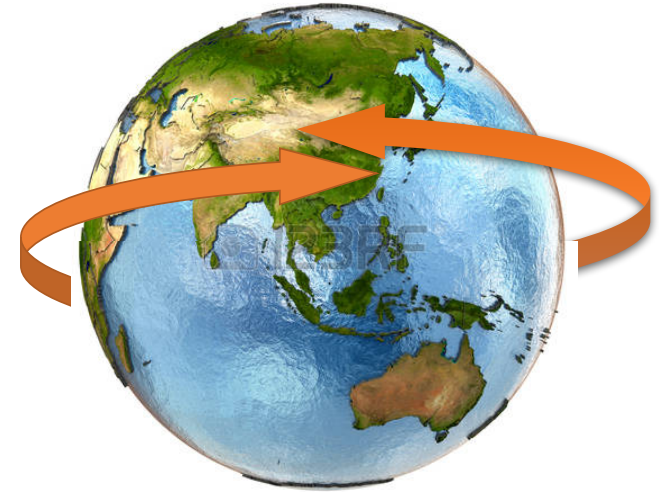
Red socks footprint?
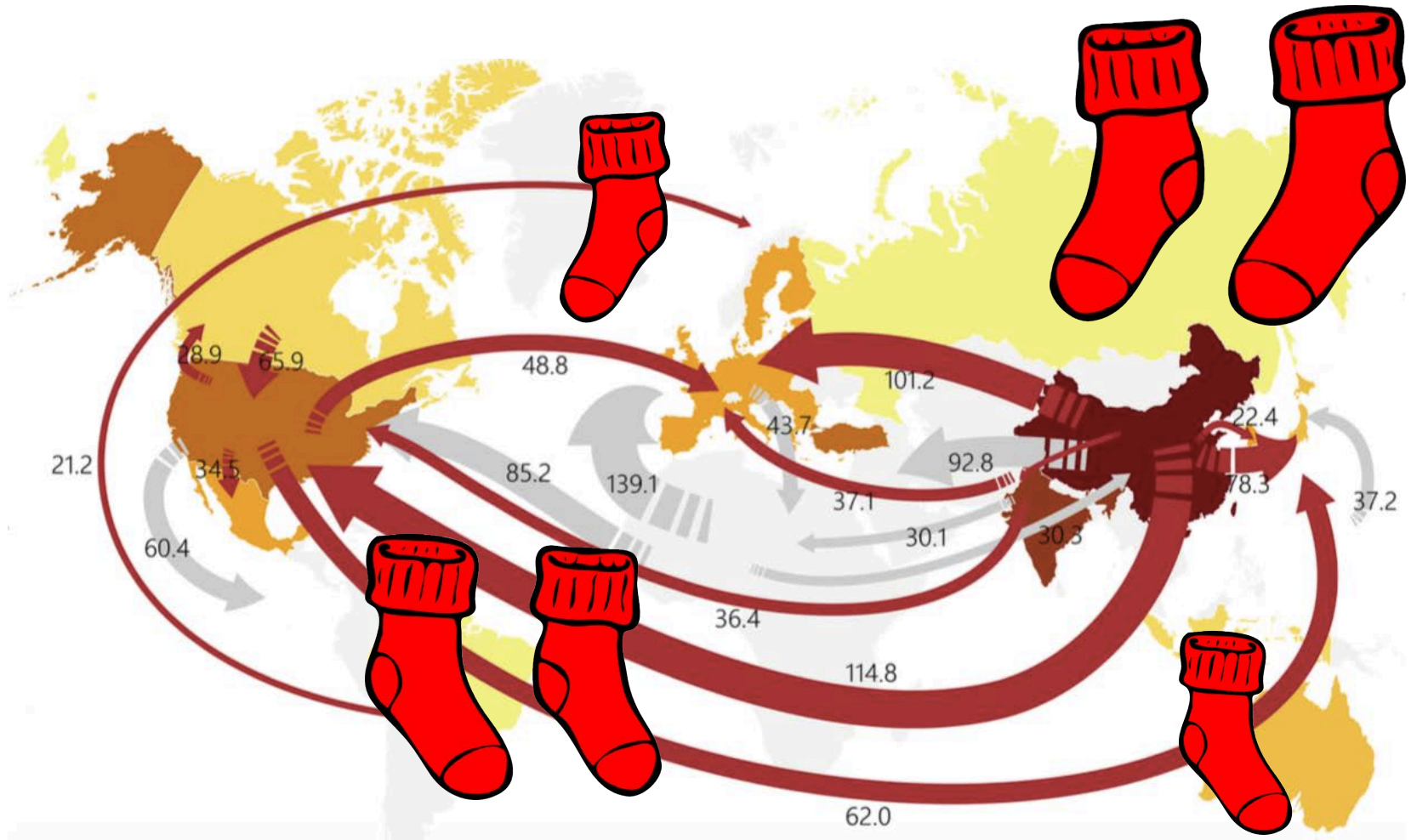
NEW

–

noticed the last 24-36 months?

Main scientific advances in recent years

New indicators
- ➢ many more environmental and social indicators
- ➢ pressure > impact > damage

Coupling of models
- ➢ physical/chemical process/transport models
- ➢ exposure / fate / life-cycle impact coupled with GMRIO

Spatial resolution
- ➢ spatial mapping and sub-national analysis linked to / nested in GMRIO

Collaboration
- ➢ virtual (G)MRIO laboratories

Shifting air pollution through trade

Lin J, Pan D, Davis SJ et al (2014) China's international trade and air pollution in the United States. *Proceedings of the National Academy of Sciences*, **111**(5), 1736-1741.
http://www.pnas.org/content/111/5/1736.abstract
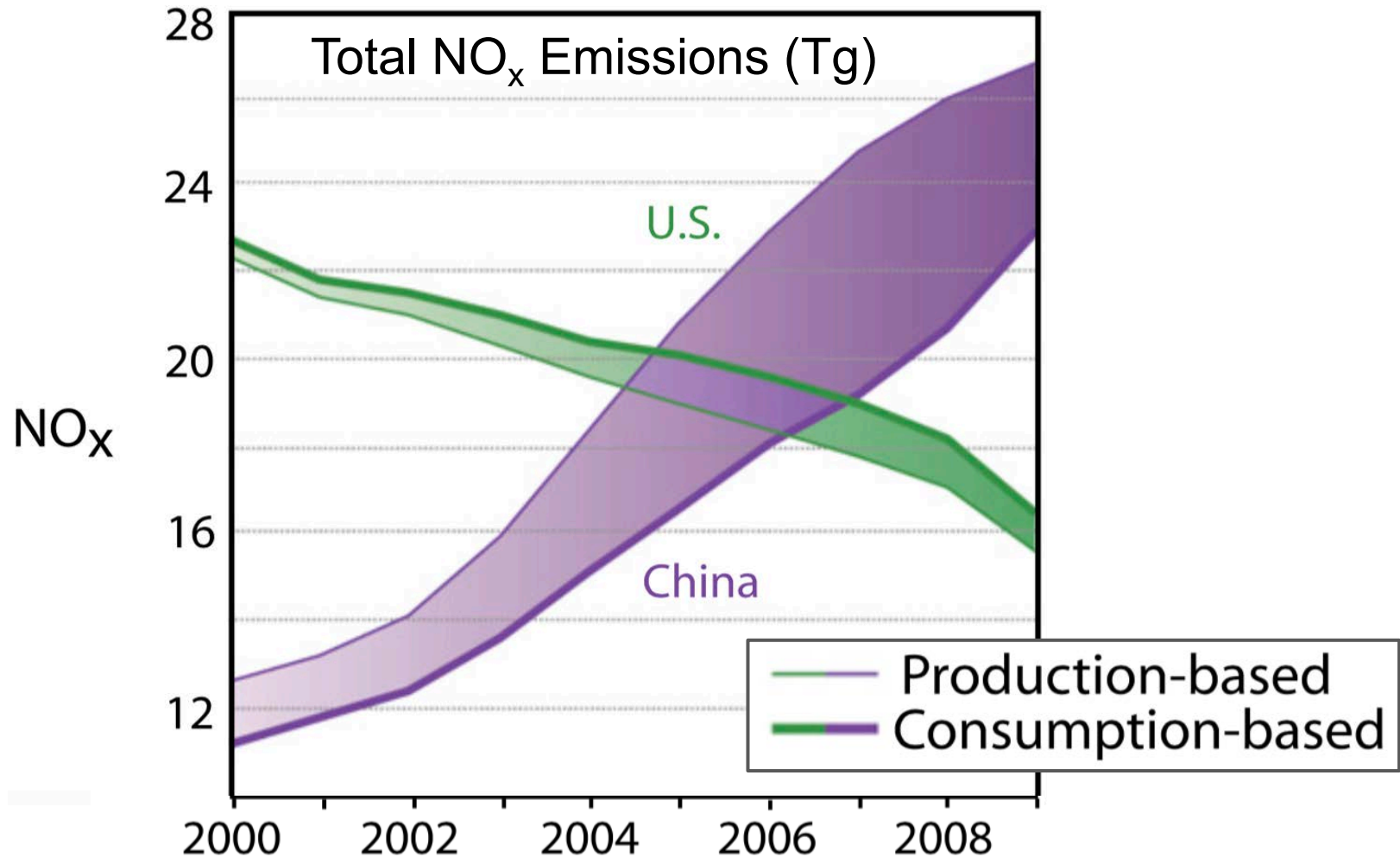
Air pollution embodied in trade: ask China
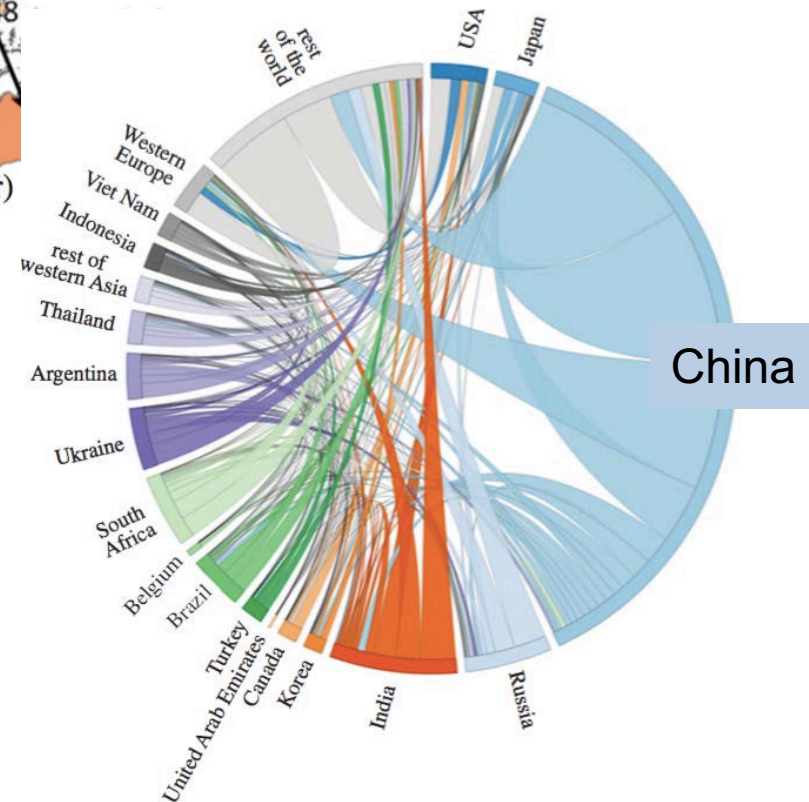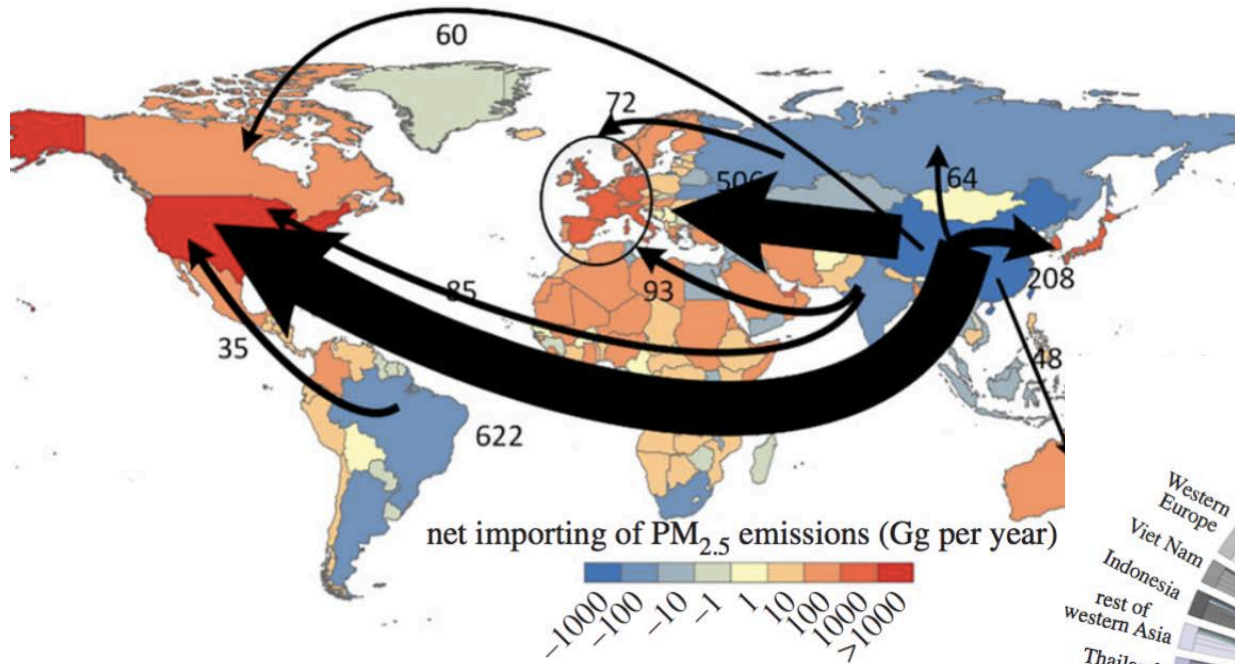
PM$_{2.5}$ emissions

GMRIO + Modelling > health impacts from PM$_{2.5}$
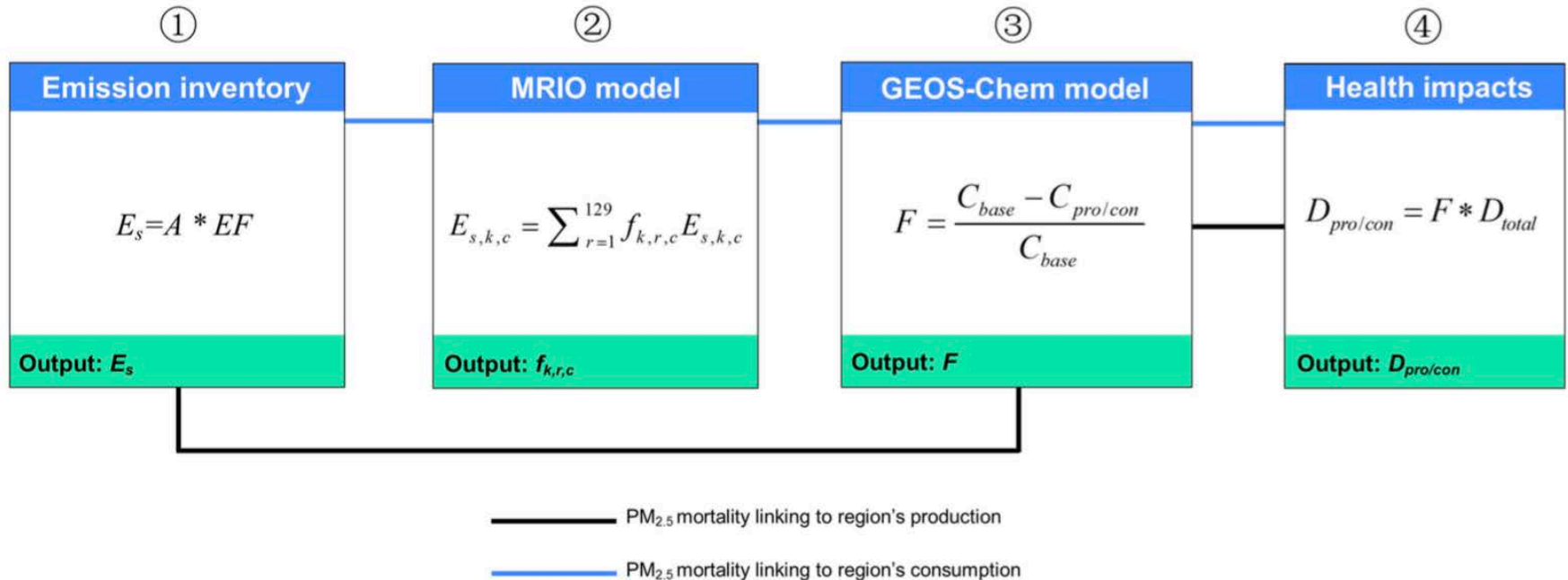
762,400 premature deaths (22%)

linked to consumption in other regions.

Zhang Q, Jiang X, Tong D, Davis SJ et al (2017) Transboundary health impacts of transported global air pollution and international trade. *Nature*, **543**(7647), 705-709. http://dx.doi.org/10.1038/nature21712

GMRIO + Modelling > atmospheric chemical transport

(a) Sulfate, min=-0.0%, max=34.2%
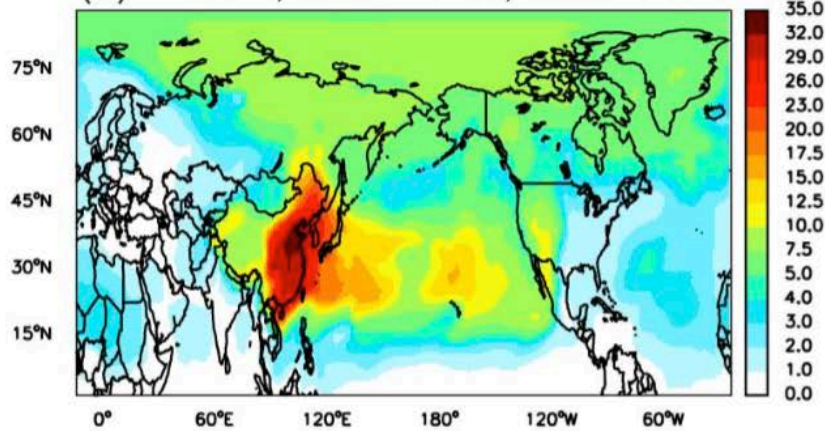
(b) Ozone, min=-7.7%, max=6.4%
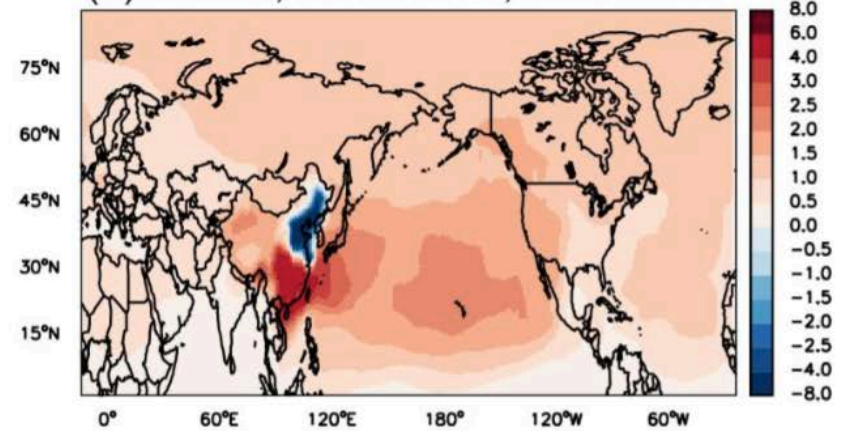
(c) BC, min=-0.0%, max=29.5%

(d) CO, min=0.0%, max=23.4%

Lin J, Pan D, Davis SJ et al (2014) China's international trade and air pollution in the United States. *Proceedings of the National Academy of Sciences*, **111**(5), 1736-1741.
http://www.pnas.org/content/111/5/1736.abstract

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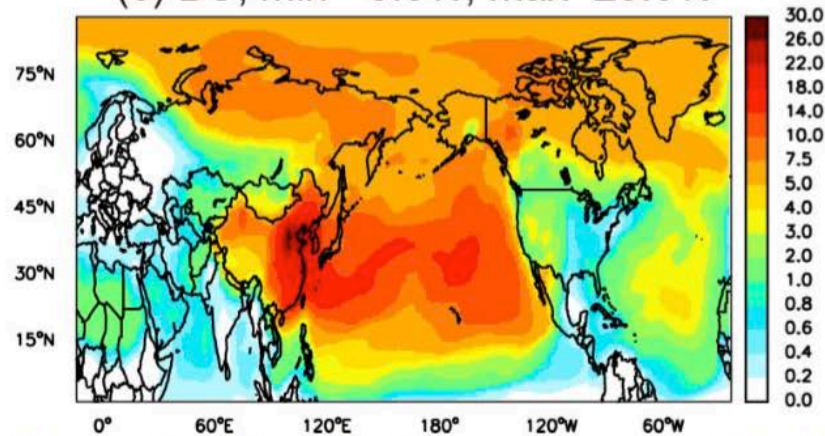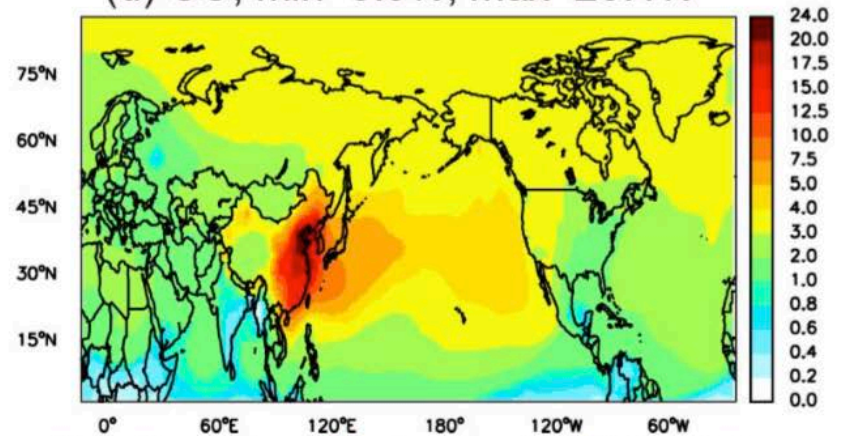
Shifting trade patterns have a stronger influence on the location of impacts from air pollution than atmospheric transport alone!

Blue water footprint of EU27 by watershed

Blue water [million m³]
- <20
- 20-80
- 80-190
- 190-370
- 370-650
- 650-990
- 990-2100
- 2100-3700
- 3700 – 5500
- >5500

Lutter S, Pfister S, Giljum S et al (2016) Spatially explicit assessment of water embodied in European trade. *Global Environmental Change*, **38**, 171-182. http://dx.doi.org/10.1016/j.gloenvcha.2016.03.001

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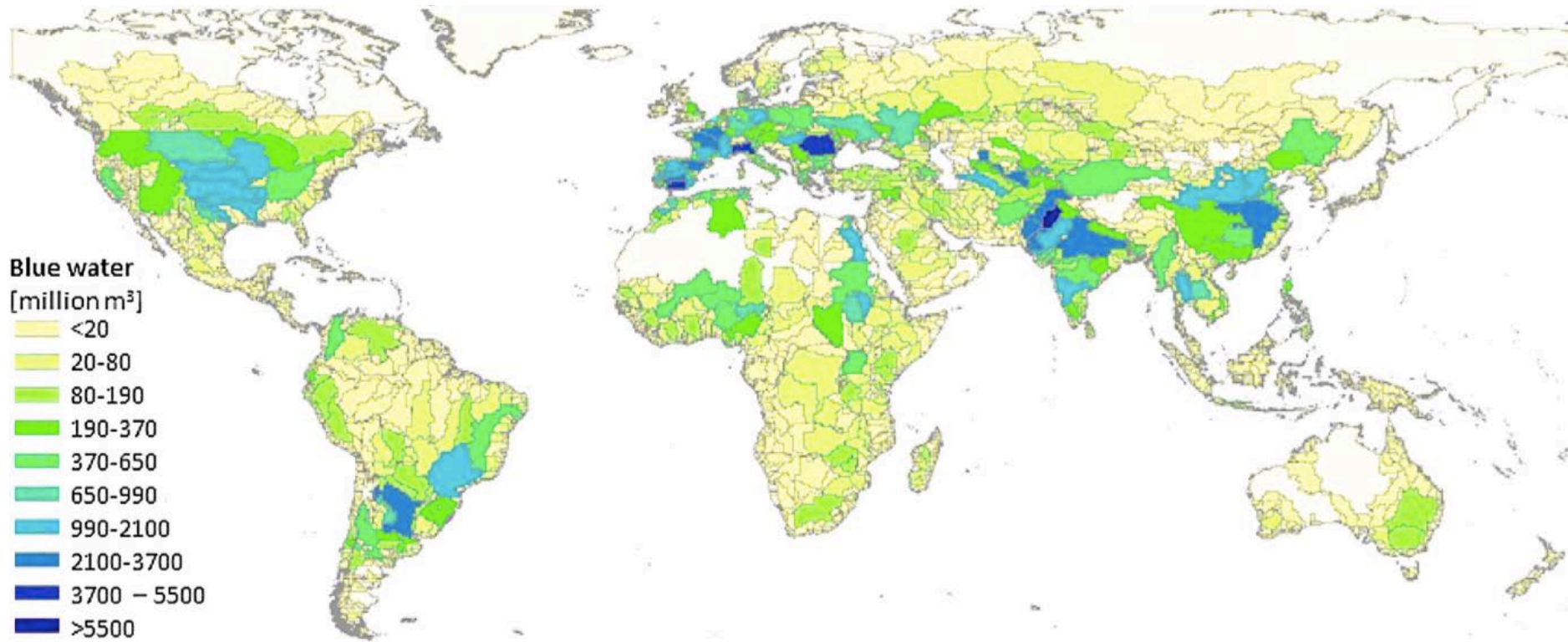
Groundwater extraction embodied in trade

Groundwater embodied in trade of crop commodities
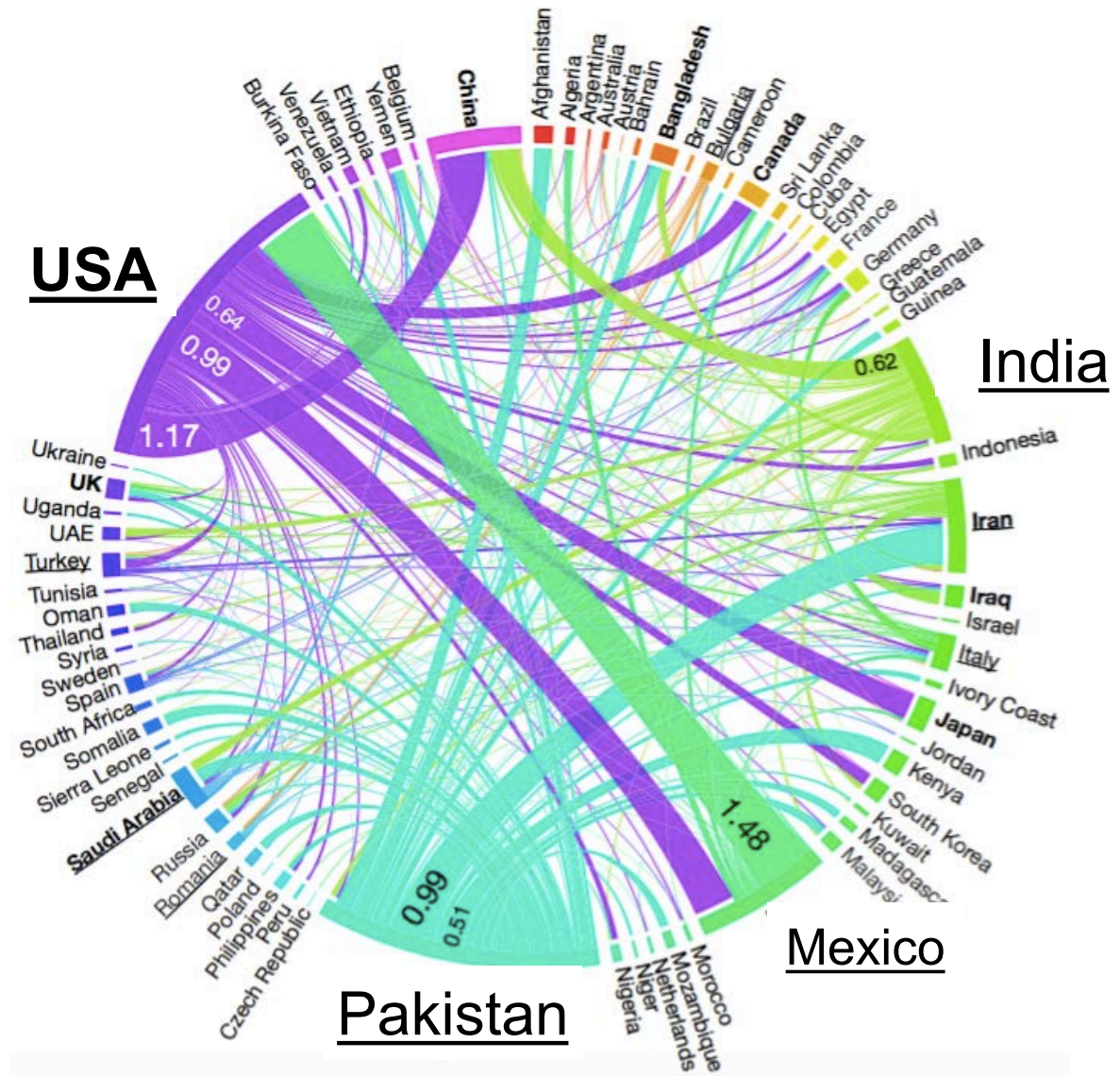
Social burdens shifted as well

16% of all global employment

17% of forced labor

18% of occupational health damage

19% of child labor

19% of vulnerable employment

20% of hazardous child labor

38% of labor by women

are embodied in international trade

Simas, M., Golsteijn, L., Huijbregts, M., Wood, R. and Hertwich, E. (2014) The "Bad Labor" Footprint: Quantifying the Social Impacts of Globalization. *Sustainability*, **6**(11), 7514-7540.
http://www.mdpi.com/2071-1050/6/11/7514

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New social footprint findings

Almost 1 million children in India work for exports alone [1]

Per 100 thousand workers per year:
- 12 fatal and 4,800 non-fatal OHS incidents
- 27,000 working days lost in global supply chains [2]

40 of the 70 million worker-years embodied in the US labor footprint come from countries with high inequality [3]

1) Gómez-Paredes et al 2016 Consuming Childhoods. *J Ind Ecol*, **20**, 611-622
2) Alsamawi et al 2017 Trade in occupational safety and health. *J Cl Prod*, **147**, 187-196
3) Alsamawi et al 2014 The Inequality Footprints of Nations. *PLoS ONE*, **9**, e110881

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Social risk footprints – Corruption

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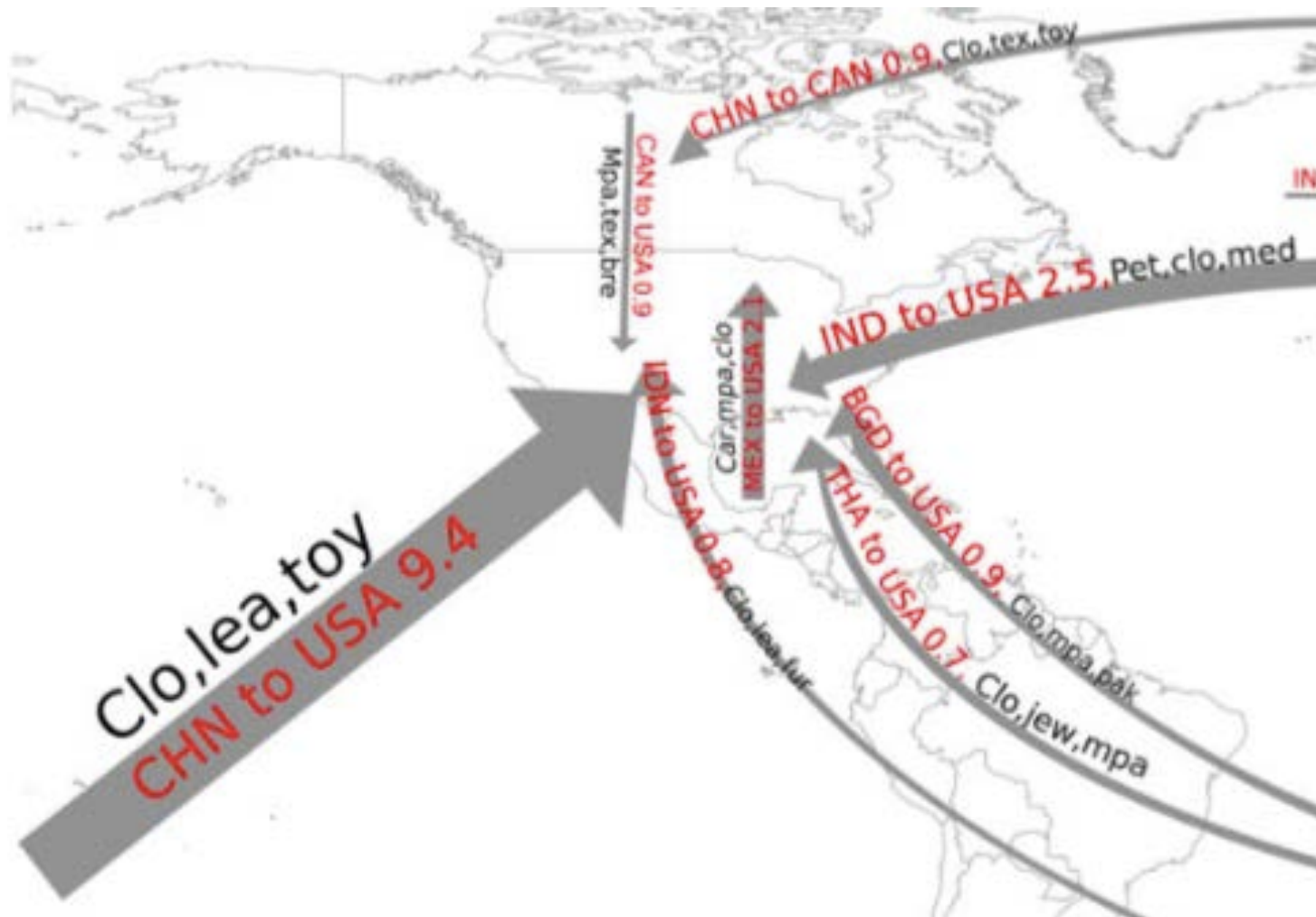
Developments in Methodologies

Footprints – from pressure to impacts

Pressure

e.g.

water footprint

land footprint

material footprint

Impact or **Damage**

e.g.

water scarcity/ pollution footprint

ecosystem damage footprint

human health damage footprint

(resource depletion footprint)

Fang, K. and Heijungs, R. (2014) Moving from the material footprint to a resource depletion footprint. *Integrated Environmental Assessment and Management*, **10**(4), 596-598. http://dx.doi.org/10.1002/ieam.1564

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It depends on how impacts are measured!

Several studies found:

> developed countries are net importers of embodied biodiversity impacts and exert 44-50% of their biodiversity footprint **in developing countries**

Lenzen et al 2012 > **threats**

Chaudhary & Kastner 2016 > **SAR**

Wilting et al 2017 > **MSA**

But:

> the actual damage to species richness occurs **in higher-income countries**

Verones et al 2017 > **LCIA**
(taking into account species vulnerability and potential extinction)

All biodiversity footprint studies confirm that food consumption is the ultimate and most important driver of biodiversity loss globally.

Land use causes twice as much biodiversity loss as GHG emissions*

*) Wilting, H. C., Schipper, A. M., Bakkenes, M., Meijer, J. R. and Huijbregts, M. A. J. (2017) Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis. *Environmental Science & Technology*. http://dx.doi.org/10.1021/acs.est.6b05296

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Our tools…
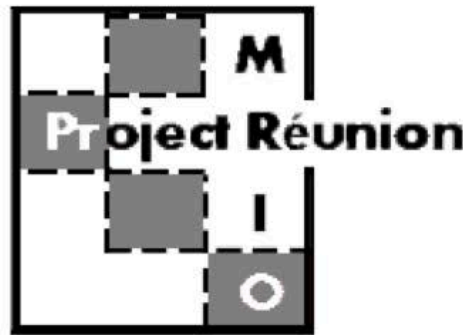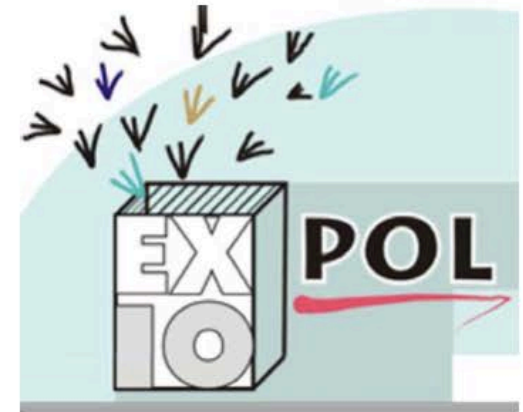
Understanding uncertainty in MRIO modelling

UK carbon footprint – Breakdown of the variation between Eora and WIOD

Owen, A., Steen-Olsen, K., Barrett, J., Wiedmann, T. and Lenzen, M. (2014) A Structural Decomposition Approach to Comparing MRIO Databases. *Economic Systems Research*, **26**(3), 262-283. http://dx.doi.org/10.1080/09535314.2014.935299

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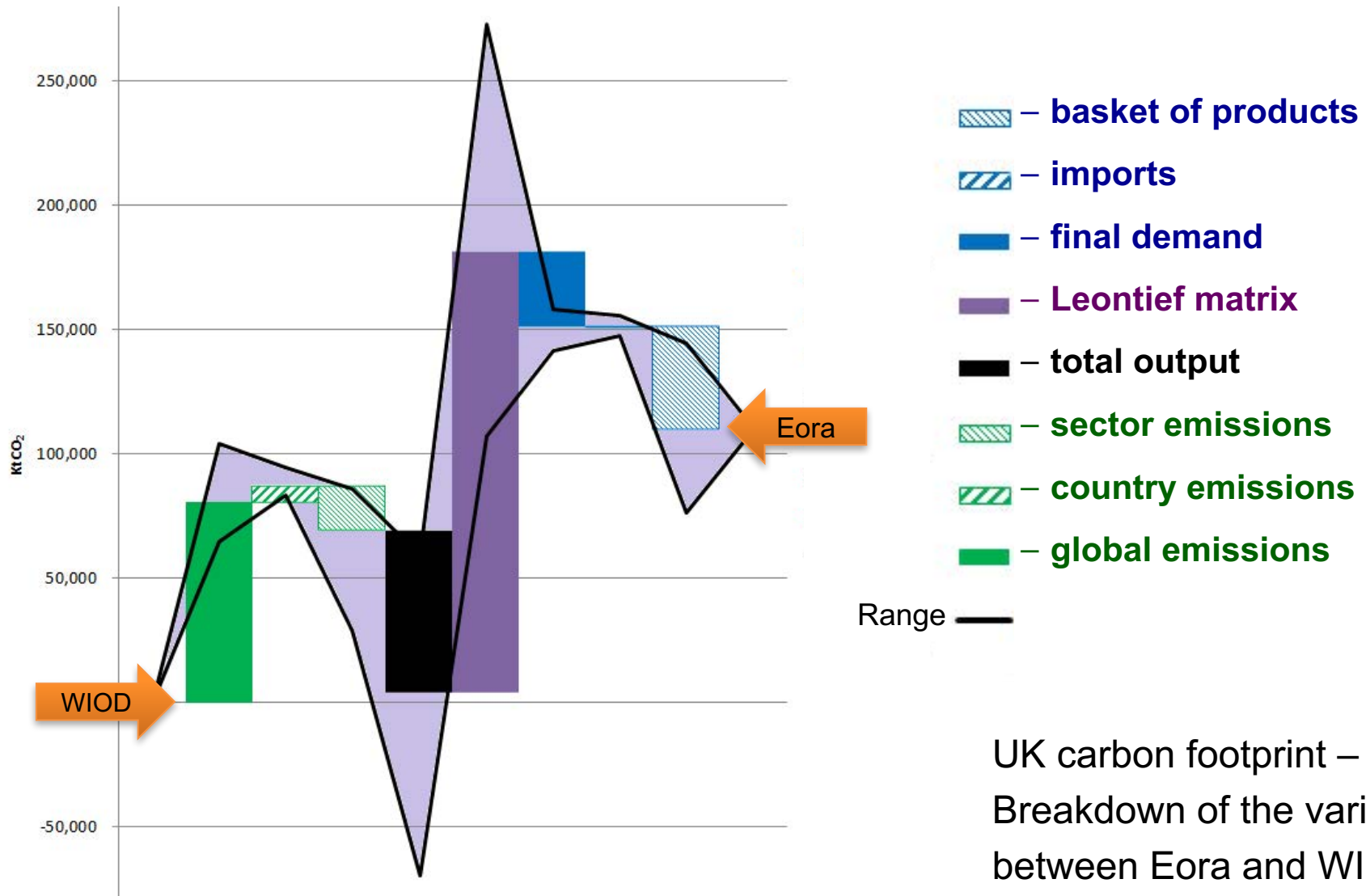
Collaborative Virtual Laboratories

Virtual Laboratories for Collaborative Input-Output Analysis

Editorial

Editorial

Virtual laboratories and MRIO analysis – an introduction >

Arne Geschke & Michalis Hadjikakou

Pages: 143-157

Published online: 22 May 2017

Global MRIOs and Virtual Laboratories

Thu, 22/Jun/2017

- Location: **Atlantic Ballroom A**   11:00 - 12:30   **Parallel Session 7**
  Topic: **(7.4) Special Session: Virtual Laboratories: Wrapping up Project Réunion and the Industrial Ecology Lab development**
  Chair: Thomas O. WIEDMANN

- Location: **Atlantic Ballroom C**   14:00 - 16:00   **Parallel Session 8**
  Topic: **(8.7) Special Session: The Current State & Future plans of Global MRIO databases (1)**
  Chair: Kirsten S. WIEBE

Fri, 23/Jun/2017

- Location: **Atlantic Ballroom 3**   14:00 - 16:00   **Parallel Session 10**
  Topic: **(10.2) Special Session: The Current State & Future plans of Global MRIO databases (2)**
  Chair: Kirsten S. WIEBE

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So What?

What Next?

—

Three Thoughts

Consumption-based footprint indicators confirm that there is little or no decoupling of impacts from economic growth

No decoupling…
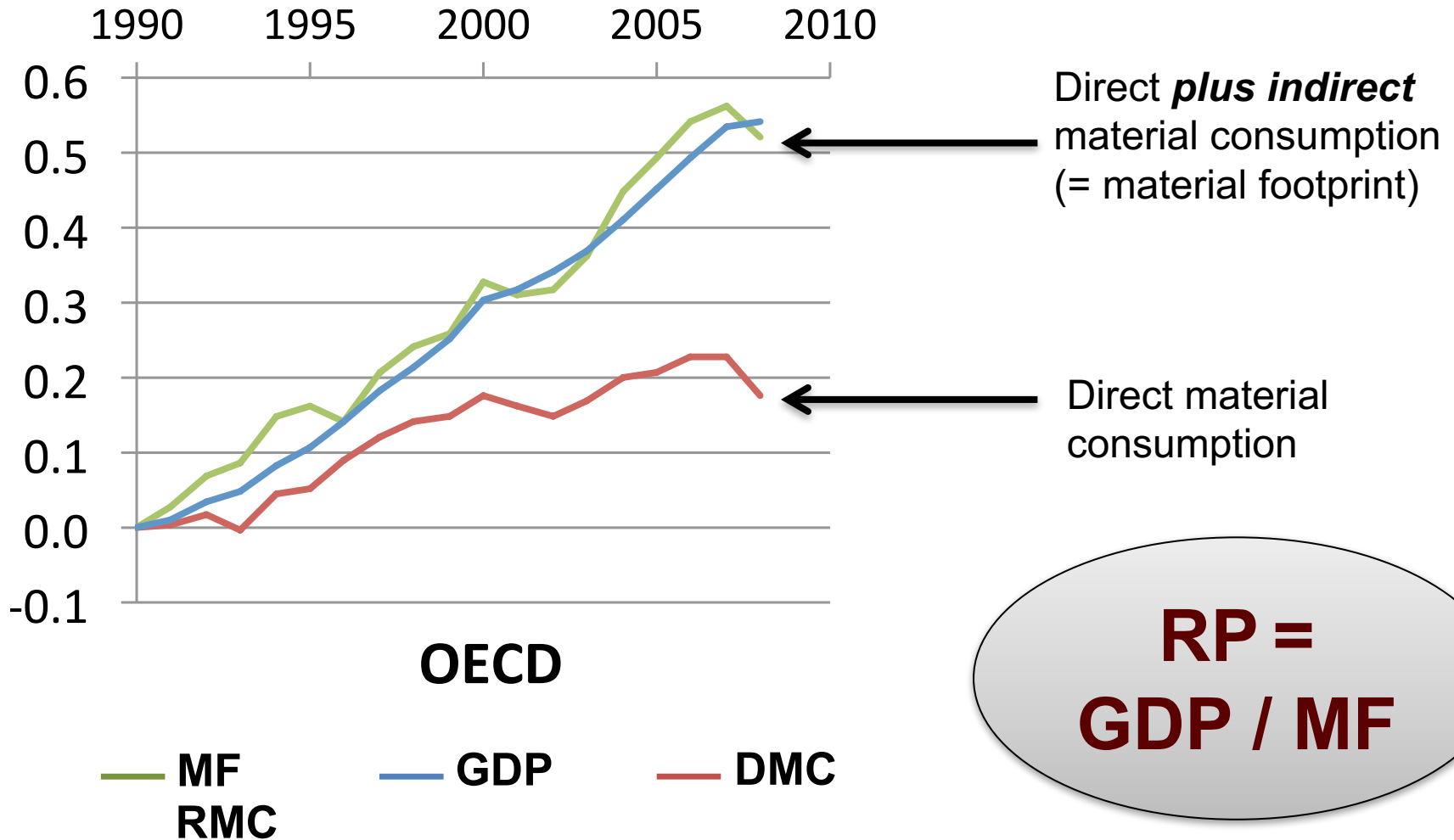
1990   1995   2000   2005   2010

Direct **plus indirect** material consumption (= material footprint)

Direct material consumption

OECD

— MF RMC   — GDP   — DMC

RP = GDP / MF

Wiedmann, T. O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J. and Kanemoto, K. (2015) The material footprint of nations. *Proceedings of the National Academy of Sciences*, **112**(20), 6271-6276. http://dx.doi.org/10.1073/pnas.1220362110

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… or little decoupling

Production | Footprint | GDP

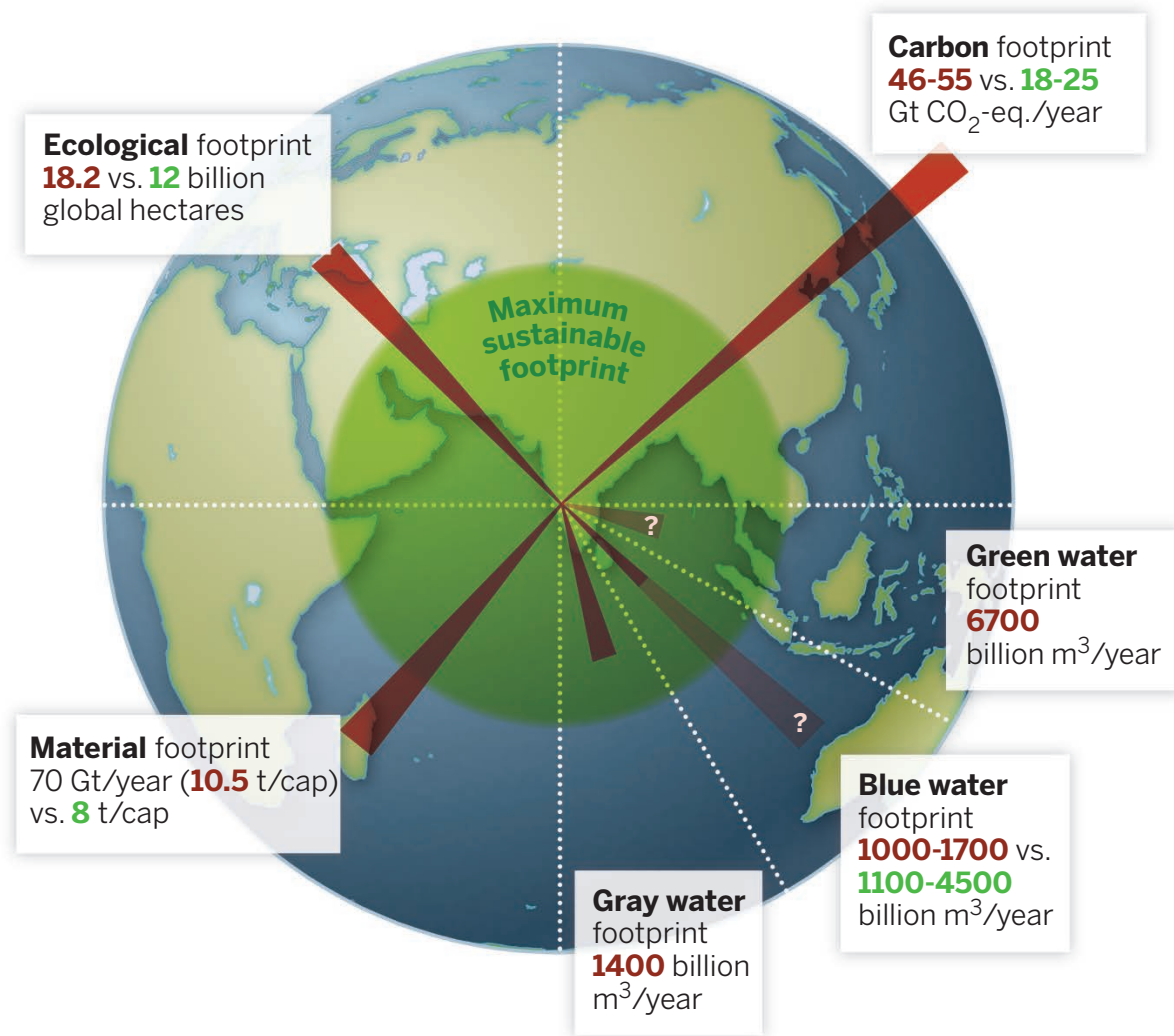| Country	Production: Waste	Production: Land	Production: Water	Production: Material	Production: Carbon	Footprint: Waste	Footprint: Land	Footprint: Water	Footprint: Material	Footprint: Ecological	Footprint: Carbon	PPP per capita
Luxembourg	2	31	39	39	1	2	3	1	2	1	1	1
Norway	20	9	24	2	7	9	5	10	5	15	8	2
United States	27	10	2	10	3	25	12	5	13	3	3	3
Ireland	38	14	31	3	8	21	8	13	1	8	4	4
Switzerland	11	33	35	34	29	14	16	17	20	14	17	5
Netherlands	3	41	30	31	16	4	7	4	12	7	11	6
Sweden	6	6	23	8	30	11	13	21	14	6	23	7
Canada	19	2	13	5	4	20	2	9	9	5	5	8
Austria	7	19	26	12	19	7	24	23	6	16	15	9
Denmark	23	28	9	9	9	12	15	12	7	2	9	10
Australia	25	1	1	1	2	22	1	2	3	10	2	11
Finland	4	4	20	4	11	3	6	22	4	9	6	12
United Kingdom	9	35	33	35	20	5	22	14	18	21	13	13
Belgium	5	39	22	27	14	8	10	8	10	4	10	14
Germany	10	34	28	24	13	6	21	18	19	23	14	15
Japan	8	37	41	40	18	10	29	28	31	27	20	16
France	16	24	14	26	31	15	9	15	23	20	27	17
Spain	17	16	4	18	26	23	20	7	17	19	24	18
Italy	21	32	12	32	24	18	25	16	25	22	22	19
Cyprus	32	36	40	7	15	29	35	31	16	26	19	20
Greece	30	21	3	17	5	17	11	3	8	18	7	21
Slovenia	13	17	36	11	22	13	19	26	15	17	16	22
South Korea	29	40	38	36	17	32	27	20	21	24	18	23
Czech Republic	22	26	27	13	12	26	34	34	27	13	21	24
Portugal	26	23	8	15	33	28	23	11	22	28	30	25
Malta	33	42	10	42	25	33	30	6	26	31	25	26
Estonia	18	8	42	6	6	16	14	29	11	11	12	27
Slovakia	15	22	21	29	23	24	31	27	29	32	26	28
Hungary	35	20	15	30	32	34	38	33	35	34	33	29
Lithuania	24	12	34	28	36	19	32	36	32	25	31	30
Latvia	40	7	37	22	38	30	18	37	28	12	32	31
Poland	14	27	32	20	21	27	37	41	30	30	29	32
Russia	1	3	16	16	10	1	4	24	33	29	28	33
Turkey	34	25	5	33	37	37	33	19	36	38	35	34
Mexico	39	13	17	37	39	39	28	30	38	35	38	35
Romania	36	18	6	14	35	38	36	25	24	39	37	36
Bulgaria	31	15	11	19	28	36	39	35	34	33	34	37
South Africa	28	11	25	23	27	35	26	40	40	37	36	38
Brazil	37	5	18	21	40	40	17	38	37	36	40	39
China	12	30	19	25	34	31	40	39	39	40	39	40
Indonesia	42	29	29	38	41	41	41	42	41	41	41	41
India	41	38	7	41	42	42	42	32	42	42	42	42

1) Quantify footprint thresholds & set targets

Carbon footprint
46-55 vs. **18-25**
Gt CO_2-eq./year

Ecological footprint
18.2 vs. **12** billion
global hectares

Maximum
sustainable
footprint

Green water
footprint
6700
billion m^3/year

Material footprint
70 Gt/year (**10.5** t/cap)
vs. **8** t/cap

Blue water
footprint
1000-1700 vs.
1100-4500
billion m^3/year

Gray water
footprint
1400 billion
m^3/year

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2) Global supply chains of companies and products

GDP or Market Value (US$bn)

Australia	1,015	Austria	414
Poland	528	Thailand	272
Indonesia	511	Ireland	268
Apple	510	Wal-Mart Stores	257
Belgium	504	Colombia	244
Switzerland	492	Portugal	243
Sweden	479	Royal Dutch Shell	243
Saudi Arabia	469	IBM	242
Norway	452	Malaysia	222
Exxon Mobil	438	Czech Republic	215

3) Machine Learning for GMRIO compilation?

SUTs
trade
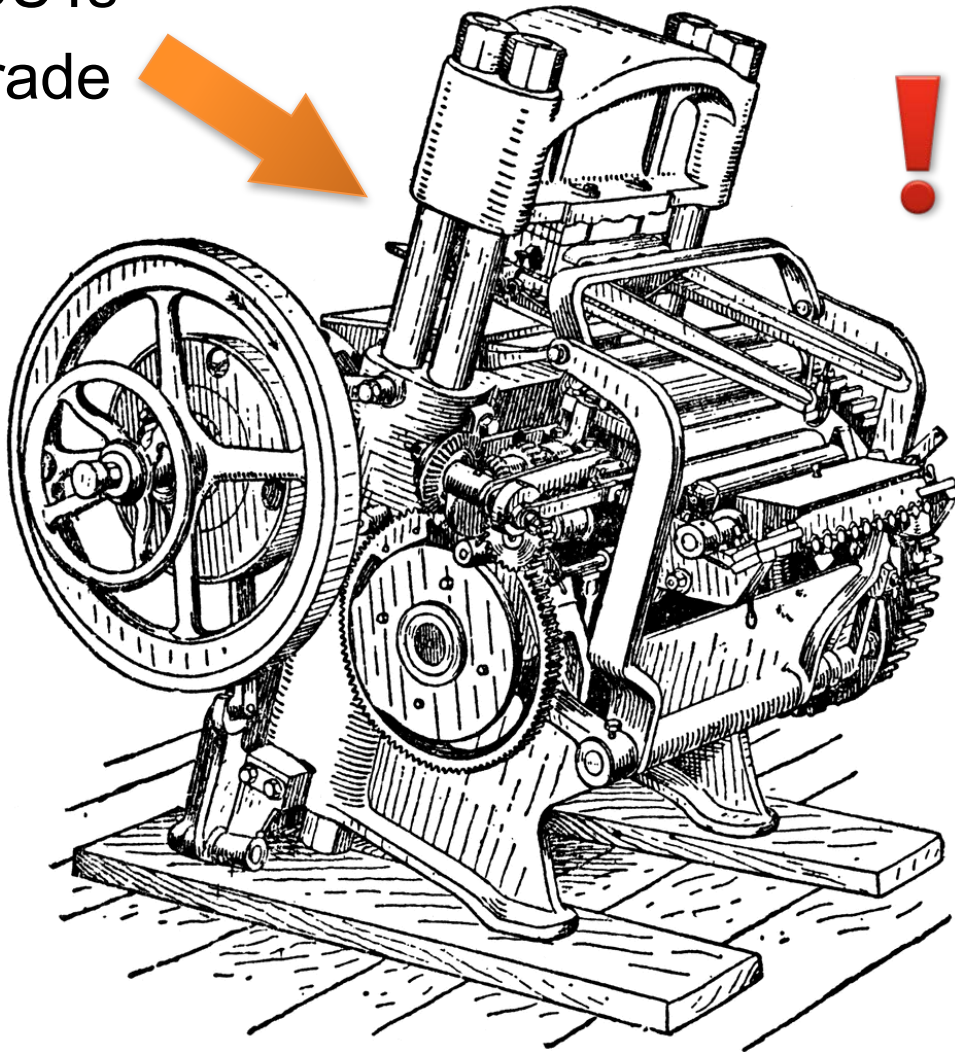
GMRIOs

Answers??!

Thank You

Don't worry about the world
coming to an end today –
it's already tomorrow in Australia

(Charles M. Schulz)

Call for Papers

Journal of Economic Structures

Special Thematic Series on

Method development in EEIOA – novel advances and best practices