The GTAP Data Base

Terrie Walmsley

Motivation for GTAP

- Established 1992
- Increasing demand for quantitative analysis of global trade issues
- Historically analysis was done “in-house” in a few agencies (no sharing with public, came and went with new administrations)
- GTAP: Combines the advantages of Agency and University approaches: documented, publicly available, easy to use.

GTAP Data Base

- Philosophy: Find the best person in the world to do the job and sell them on it!
- GTAP establishes standards, coordinates the work and brings it together into ONE globally consistent data base.
  - Global coverage: 129 regions in v8 (vs. 13 in version 1)
  - Sectoral detail: 57 sectors (vs. 37 in version 1)
  - Two base years in v8: 2004 and 2007
  - Bilateral trade data and shipping margins: USDA, CPB
  - Protection data: ITC-Geneva, CEPII, OECD…
  - National data bases: national collaborators
  - Physical data - energy sectors (IEA, OLADE)

I-O Tables

- Contributed by Individuals
- Sectoral classification:
  - Full 57 sectors not required
  - Separate food and agriculture, energy, other
  - Separate domestic and import use
- Sign conditions: no negative flows except in changes in stocks
- Sectoral balance condition: Sales = Costs
- Check for Unusual Shares

Clean, Disaggregate, Synthesize

- Disaggregate
  - Of the 112 regions in GTAP 7.1: only 36 I-O tables have all 57 sectors; no disaggregation needed
  - 40 tables need agricultural disaggregation; use agricultural I-O data set.
  - 17 tables need non-agricultural disaggregation; use representative table.
- Synthesize
  - Create 19 composite regions.

International Data Sets: 244 Countries

Volumes and Prices: IEA

energy data sets

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E/CSE),

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macro data set

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protection data sets

trade data sets

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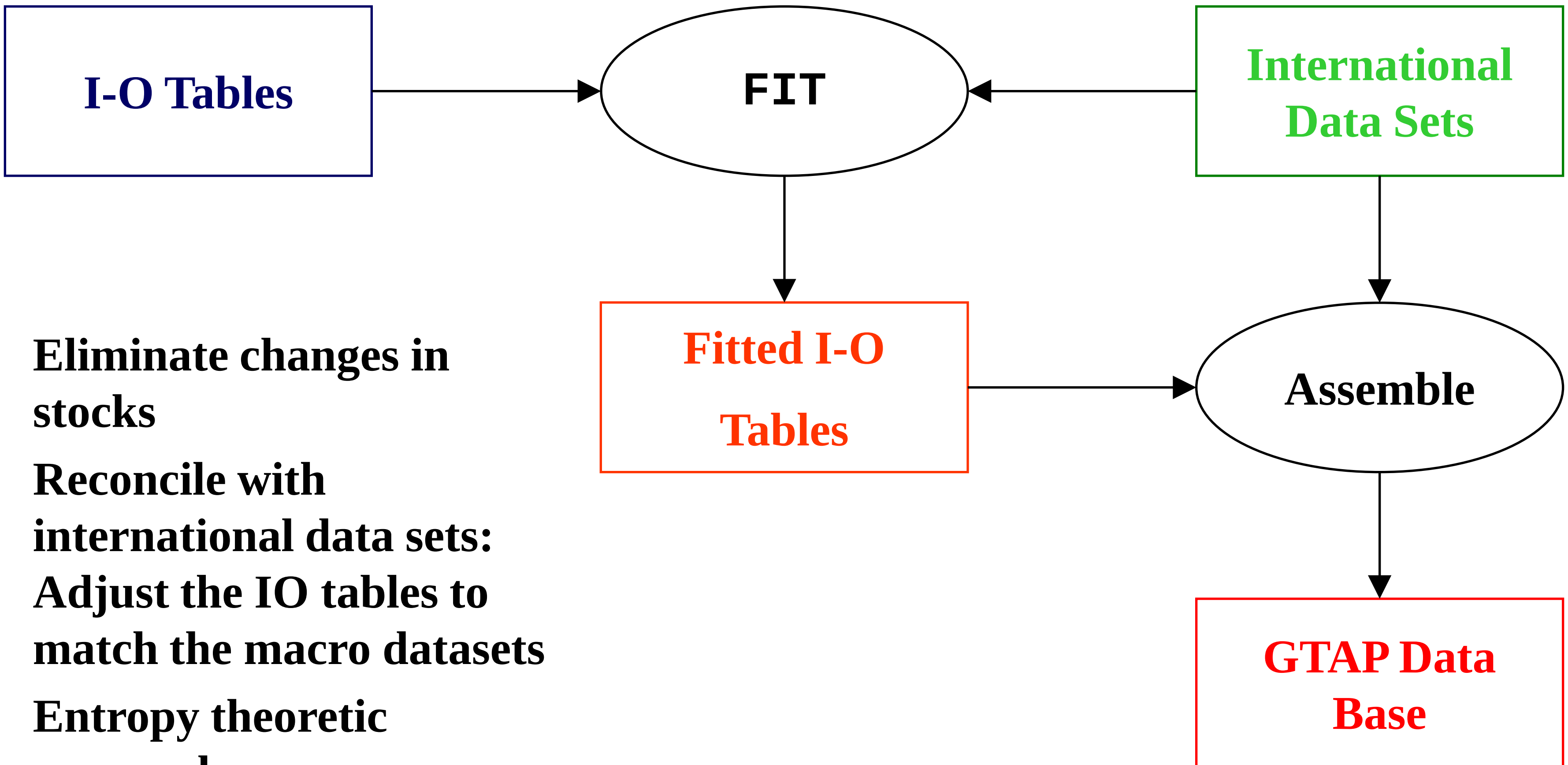
Income and Factor Taxes

agricultural data set

Construction Process



- Eliminate changes in stocks
- Reconcile with international data sets: Adjust the IO tables to match the macro datasets
- Entropy theoretic approach

Satellite Datasets

- Energy volumes
- CO_2 and non-CO_2 emissions
- Land use by Agro-ecological zone
- Migration and remittances
- Foreign income payments and receipts
- FDI

Future Improvements on the Agenda

- IO tables
  - Commodity Taxes
  - Dwellings
- Skill shares
- Intra-institutional detail
- Improved international margins
- Domestic margins
- IRIO

IRIO

- **GTAP is an MRIO (imports by agent and bilateral imports, but not bilateral imports by agent)**
- **Collaborating with Zhi Wang (USITC)**
  - **GTAP compatible IRIO which we hope to adapt**
    - **Used BEC to split imports into intermediate, final and mixed**
    - **Collected additional data on China and Mexico**
    - **Collected additional IO information where available**
  - **Optimization assuming fixed bilateral trade.**

Theoretical Background

FIT Module

- **Bacharach, M. (1970),** ***Biproportional matrices and input-output change*****, Cambridge.**
- **James, M. and R. McDougall (1993), "FIT: An input-output data update facility for SALTER",** ***SALTER working paper 17*****, Australian Industry Commission.**
- **Theil, H. (1967),** ***Economics and information theory*****, North-Holland, Amsterdam.**

A Multi-Region Input-Output Table
based on the
Global Trade Analysis Project
database
(GTAP-MRIO)

Glen Peters and Robbie Andrew
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Outline

- Historic Development
- Goals and Motivation
- Construction and Solution
- MRIOT “Construction” Applications
    - Region detail
    - Sector detail
    - Small elements
    - Model comparisons

Policy Analysis

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CO_2 Embodied in International Trade with Implications for Global Climate Policy

GLEN P. PETERS* AND
EDGAR G. HERTWICH

Carbon Footprint of Nations: A Global, Trade-Linked Analysis

Environ. Sci. Technol. **2009,** *43,* 6414–6420

EDGAR G. HERTWICH*,† AND
GLEN P. PETERS†,‡

PNAS

Growth in emission transfers via international trade from 1990 to 2008

Glen P. Peters[a,1], Jan C. Minx[b,c], Christopher L. Weber[d,e], and Ottmar Edenhofer[c,f]

PNAS

The supply chain of CO_2 emissions

Steven J. Davis[a,1], Glen P. Peters[b], and Ken Caldeira[a]

nature climate change
LETTERS
PUBLISHED ONLINE: 22 JANUARY 2012 | DOI: 10.1038/NCLIMATE1371

Pathways of human development and carbon emissions embodied in trade

Julia K. Steinberger[1,2]*, J. Timmons Roberts[3], Glen P. Peters[4] and Giovanni Baiocchi[5]

Rapid growth in CO_2 emissions after the 2008–2009 global financial crisis

Historic Development

- Motivated by climate policy (carbon leakage)
- Initial single-region MRIOT on Norway
  - Peters and Hertwich 2006 (x3)
- Relevance required a global study
  - Use the GTAP database to get a ***timely*** solution
  - EEBT, Peters and Hertwich (2008), *ES&T*
  - MRIO, Hertwich and Peters (2009) , *ES&T*
  - Time, Peters et al (2011), *PNAS*

Goal and Motivation

- Timely and policy relevant analysis
  - *Not MRIOT construction methods*

- GTAP-MRIO
  - We *use* the GTAP database
  - We don’t intent to place ownership
    - (not CICERO-MRIO)

Construction (GTAP-MRIO)

$$Z_{MRIO} = \begin{pmatrix} Z_1^d + \hat{S}_{11} Z_1^i & \hat{S}_{12} Z_2^i & \cdots & \hat{S}_{1m} Z_m^i \\ \hat{S}_{21} Z_1^i & Z_2^d + \hat{S}_{22} Z_2^i & \cdots & \hat{S}_{2m} Z_m^i \\ \vdots & \vdots & \ddots & \vdots \\ \hat{S}_{m1} Z_1^i & \hat{S}_{m2} Z_2^i & \cdots & Z_m^d + \hat{S}_{mm} Z_m^i \end{pmatrix}$$

GTAP nomenclature:

$Z^d = VDFM$, $Z^i = VIFM$,

$T = VXMD$, $S = VXMD/VIM$

Construction (GTAP-MRIO)

$$Z_{MRIO} = Z^d + SZ^i$$

$$Z^d = \begin{pmatrix} Z_1^d & 0 & \cdots & 0 \\ 0 & Z_2^d & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Z_m^d \end{pmatrix}$$

$$T = \begin{pmatrix} \hat{T}_{11} & \hat{T}_{12} & \cdots & \hat{T}_{1m} \\ \hat{T}_{21} & \hat{T}_{22} & \cdots & \hat{T}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{T}_{m1} & \hat{T}_{m2} & \cdots & \hat{T}_{mm} \end{pmatrix} \qquad Z^i = \begin{pmatrix} Z_1^i & 0 & \cdots & 0 \\ 0 & Z_2^i & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Z_m^i \end{pmatrix}$$

Construction (Rutherford)

$$\underbrace{x^{y}_{gr}\ vom_{gr}}_{\text{Total Embodied Carbon}} = \underbrace{co2e_{gr}}_{\text{Direct Carbon}} + \underbrace{\sum_i x^{m}_{ir}\ vifm_{igr}}_{\text{Indirect Imported}} + \underbrace{\sum_i x^{y}_{ir}\ vdfm_{igr}}_{\text{Indirect Domestic}}$$

$$\underbrace{x^{m}_{ir}\ vim_{ir}}_{\text{Carbon Embodied in Imports}} = \underbrace{\sum_s x^{y}_{is}\ vxmd_{isr}}_{\text{Carbon in Goods}} + \underbrace{\sum_j x^{t}_{j}\ vtwr_{jisr}}_{\text{Carbon in Transportation}}$$

$$R = \begin{pmatrix} Z^{d} & T \\ Z^{i} & 0 \end{pmatrix}$$

$$F^{total}(I - R\hat{z}^{-1}) = F^{direct} \qquad F^{direct} = (F^{d}\ 0) \qquad F^{total} = (F^{t}\ F^{*}),$$

GTAP-MRIO vs Rutherford

$$Z_{MRIO} = Z^d + SZ^i$$

$$R = \begin{pmatrix} Z^d & T \\ Z^i & 0 \end{pmatrix}$$

[3] R uses the domestic and imported IOTs and bilateral trade data and has $2*(n_c*n_c*n_r) + n_c*n_r*n_r$ non-zero elements and in GTAP7.1 ($n_c=57$, $n_r=112$) R has 1,442,784 elements. Meanwhile, Z_{MRIO} distributes this data and has $(n_c*n_r)*(n_c*n_r)$ = 40,755,456 non-zero elements (about 30 times more than R). The dimensions of R are $2n*2n$ (where $n=n_c*n_r$), while the dimensions of Z_{MRIO} are $n*n$.

GTAP-MRIO vs Rutherford

Table 1: Construction and solution times for several methods using the same data.

	Tol	Iterations	Construction time[b,c] (s)	Solution time[c] (s)	Max relative error (%)[a]
GTAP-MRIO					
Gaussian Elimination	–	–	0.91	6.02	–
Rutherford					
Gaussian Elimination	–	–	0.19	13.5	<1e-15
Taylor Series expansion	10^{-16}	753	0.19	1.67	1.57e-12
Taylor Series expansion	10^{-10}	425	0.19	0.94	1.85e-6
Taylor Series expansion	10^{-5}	152	0.19	0.34	0.182

[a] Compared to GTAP-MRIO

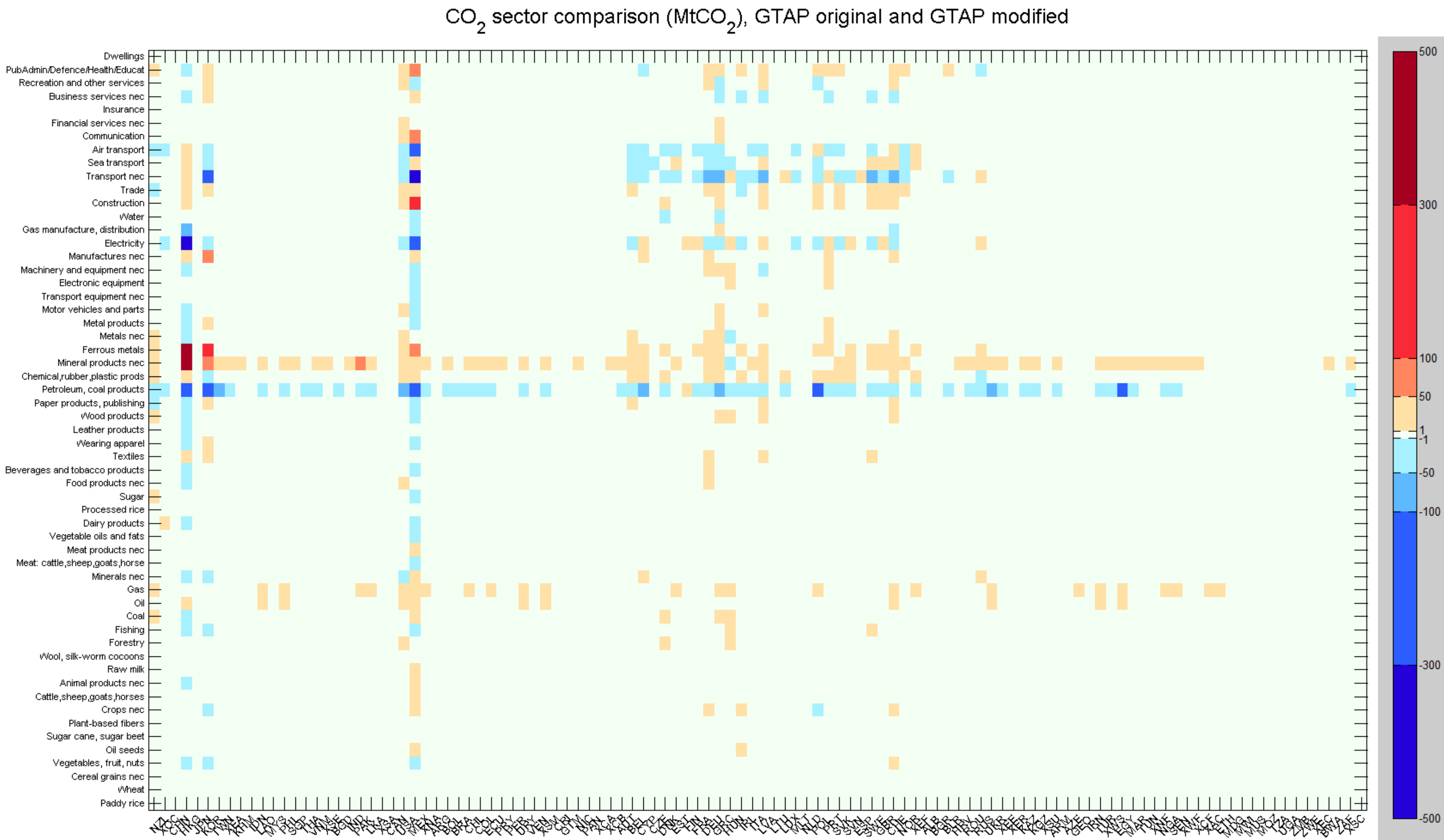
[b] Construction times are after the GTAP data is loaded (thus, is to place elements in a block matrix)

[c] We used Matlab R2011b with an Intel Core i5 @ 2.5 GHz, 8GB RAM, 64-bit Windows.

Environmental Extensions

- Total emissions (see later)
- Allocation to sectors important
- GTAP
  - Energy and CO_2 consistent
    - but different to national sources…
- GTAP+
  - Match national sources
    - but inconsistent with GTAP energy data
- What is “best”?

Difference: GTAP vs GTAP+

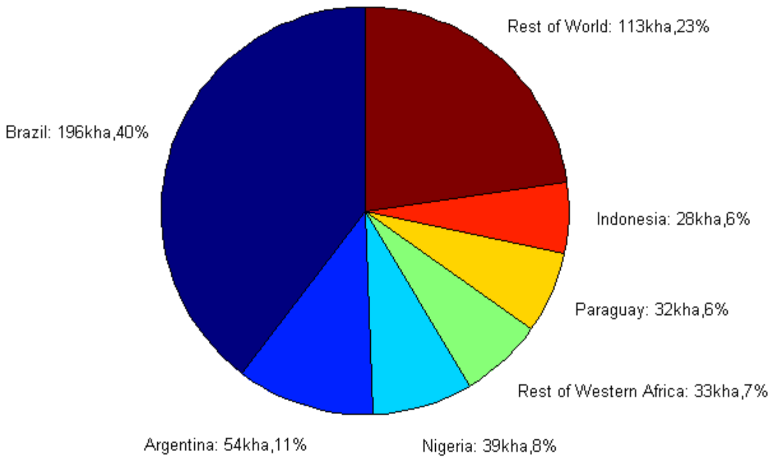


Region Aggregation

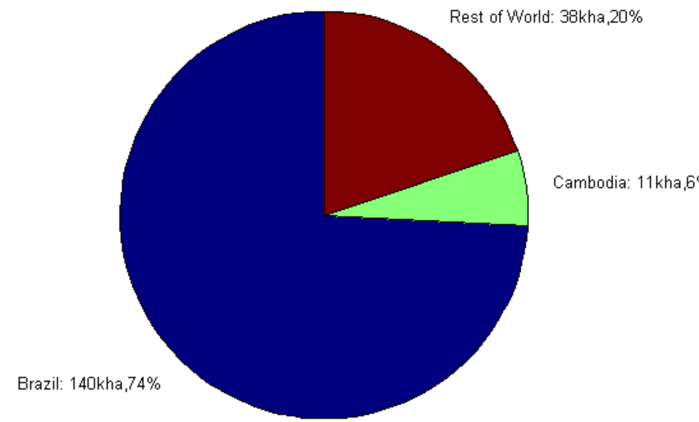
- GTAP-MRIO:
  - 78 (1997), 87 (2001), 112 (2004), 129 (2007)
- Andrew et al (2009)
  - A carbon footprint needs four regions + RoW
  - Several shortcuts possible, like uni, DTA, etc
- Experience shows that regional detail is important
  - You never know which regions are needed
  - Adding regions is like adding sectors

EU27 → Deforestation

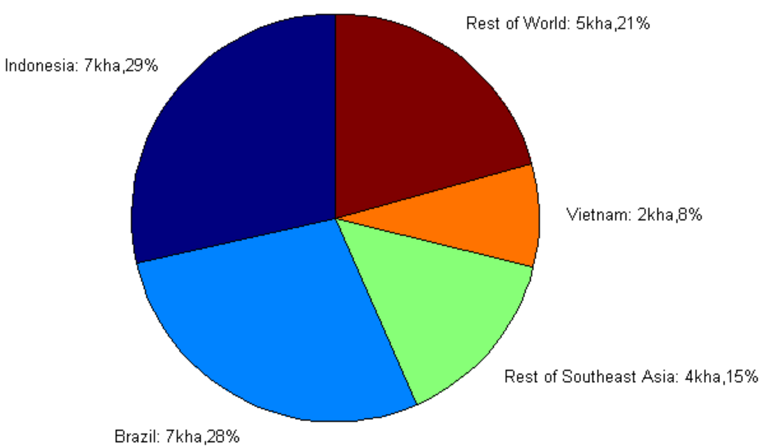
Import of deforested crop land use into EU27: 495kha



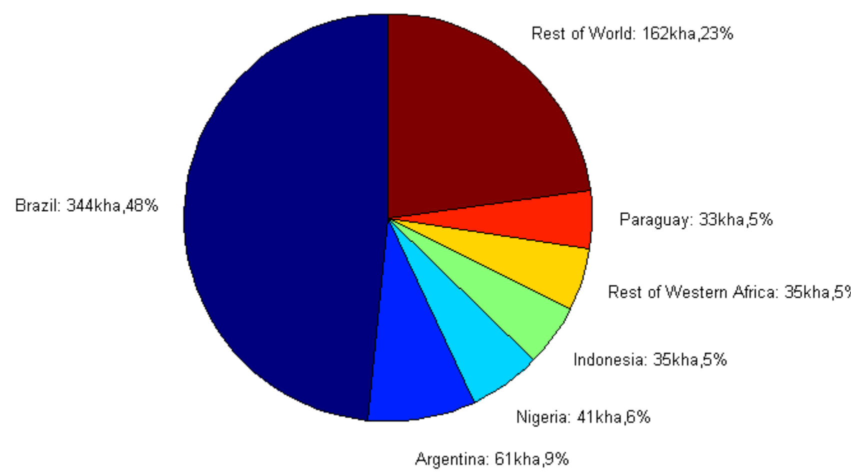
Import of deforested pasture land use into EU27: 189kha



Import of deforestation due to logging into EU27: 26kha



Import of deforested total land use into EU27: 710kha



Sector Aggregation

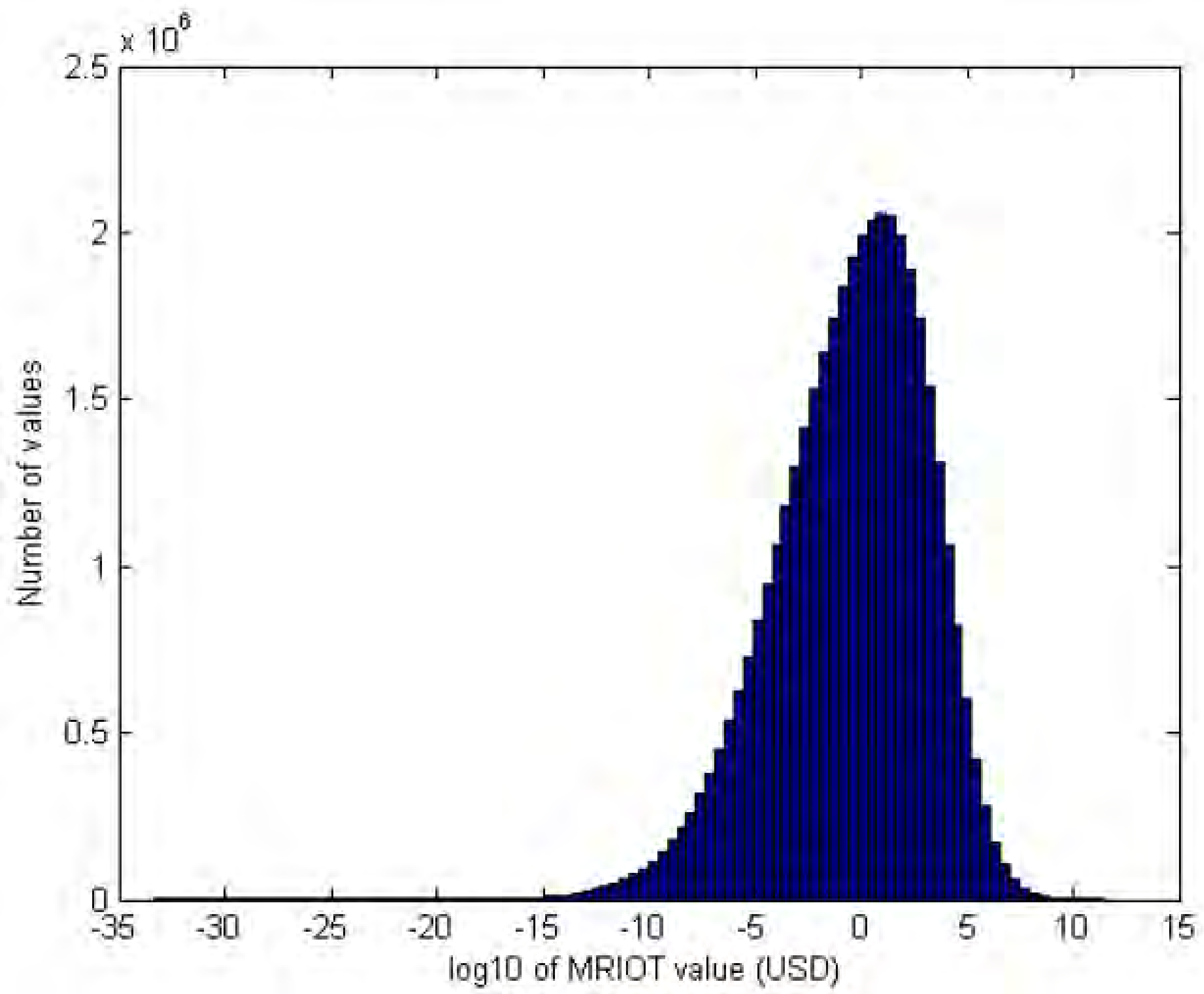
- GTAP-MRIO:
  - 57 sectors, all versions
- *When is detailing needed?*

- Analysis of aluminium sector
  - Dis-aggregation required
- Analysis of carbon footprints
  - ?

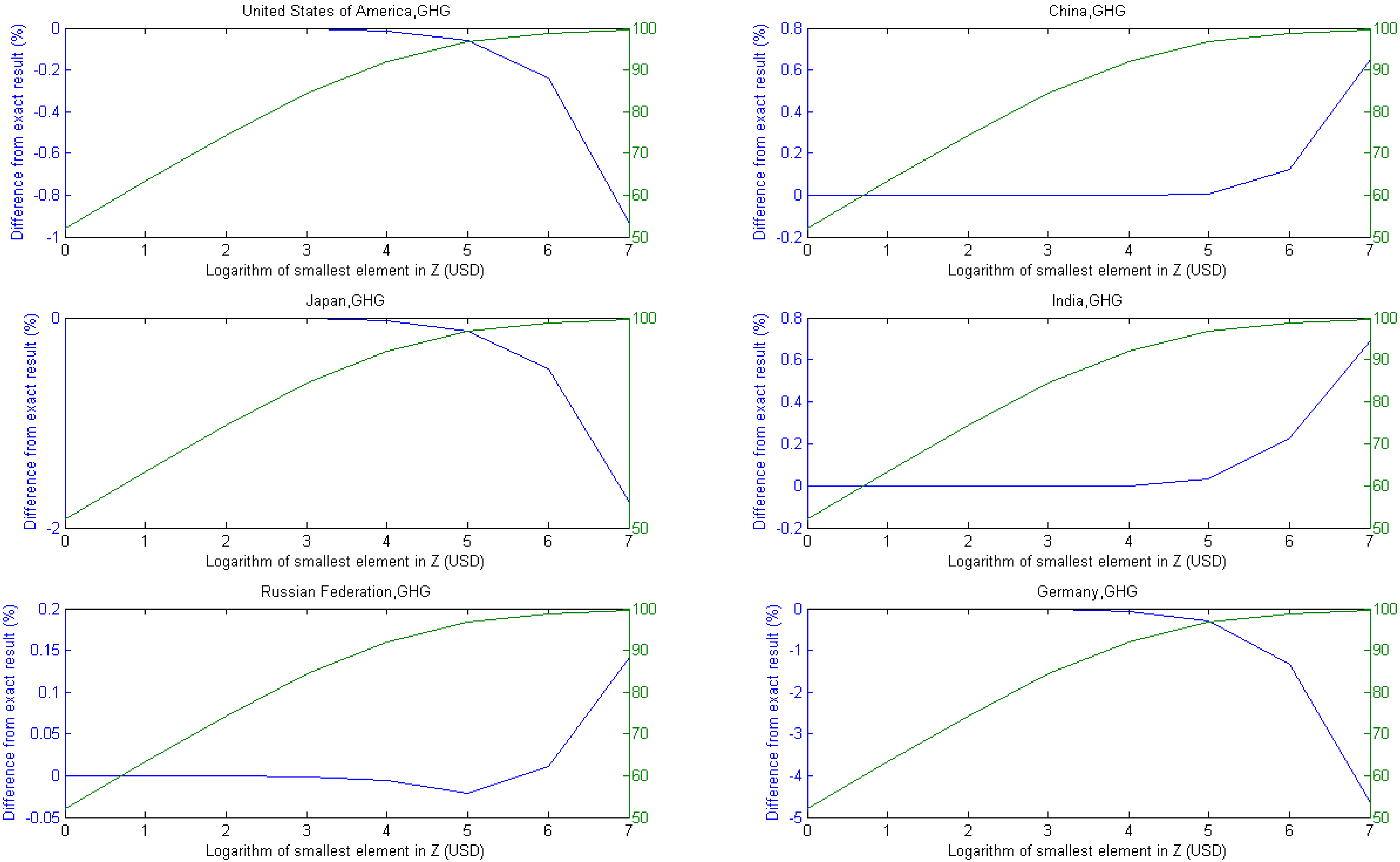
Table 2: The carbon footprint including the well-mixed greenhouse gases in the Kyoto Protocol with the full GTAP-MRIOT with 57 sectors, and an aggregated version with 8 sectors.

			Carbon footprint with 57 sectors (GHG $MtCO_2$-eq)	Carbon footprint with 8 sectors (GHG $MtCO_2$-eq)	Difference (GHG $MtCO_2$-eq)	Difference (%)
Top 5 emitters	USA	United States of America	7864	8031	-168	-2
	CHN	China	5098	4926	172	3
	JPN	Japan	1772	1821	-49	-3
	IND	India	1642	1655	-13	-1
	RUS	Russian Federation	1601	1571	30	2
Top 5 relative change	XWF	Rest of Western Africa	172	149	23	14
	XEA	Rest of East Asia	109	94	15	14
	XSE	Rest of Southeast Asia	87	70	18	20
	PRY	Paraguay	29	23	6	20
	URY	Uruguay	24	28	-3	-14
Bottom 5 emitters	XSM	Rest of South America	11	11	0	0
	ARM	Armenia	8	8	0	4
	XEF	Rest of EFTA	8	8	0	-4
	MUS	Mauritius	6	6	0	6
	MLT	Malta	5	5	0	1

Small Terms



x 10^6
2.5
2
1.5
1
0.5
0
Number of values
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
log10 of MRIOT value (USD)



United States of America,GHG
China,GHG
Japan,GHG
India,GHG
Russian Federation,GHG
Germany,GHG
Difference from exact result (%)
Logarithm of smallest element in Z (USD)

Study Comparisons

- What causes largest differences
  - Variations in environmental extensions
  - Definition of the Carbon Footprint
  - Different MRIOT

Environmental Extensions

		MRIO carbon footprint (GTAP GHG $MtCO_2$-eq)	MRIO carbon footprint (GTAP+ GHG $MtCO_2$-eq)	MRIO carbon footprint (EDGAR GHG $MtCO_2$-eq)	Range (GHG $MtCO_2$-eq)	Range (%)
Largest 10 absolute differences	China	4920	5040	5542	622	12.3
	United States of America	8125	7704	7890	421	5.5
	India	1612	1630	1949	338	20.7
	Ethiopia	280	279	81	198	71.0
	Japan	1762	1728	1899	171	9.9
	Chile	246	244	94	152	62.2
	Rest of Western Asia	1109	1068	962	147	13.8
	Germany	1353	1255	1394	139	11.1
	Russian Federation	1598	1588	1726	138	8.7
	Brazil	762	744	882	138	18.5
Largest 10 relative differences	Bolivia	34	33	91	58	172.9
	Rest of South Central Africa	117	118	217	100	84.8
	Rest of North America	12	12	4	9	71.7
	Madagascar	72	72	22	50	69.3
	Zambia	27	27	41	14	52.7
	Malawi	14	14	7	7	51.8
	Rest of Southeast Asia	88	87	131	44	50.7
	Zimbabwe	38	38	20	18	47.2
	Senegal	33	33	20	13	40.2
	Malaysia	231	227	143	88	38.8

Carbon Footprint Definition

		MRIO carbon footprint (GHG $MtCO_2$-eq)	EBT carbon footprint (GHG $MtCO_2$-eq)	Difference (GHG $MtCO_2$-eq)	Difference (%)
Largest 10 absolute differences	Taiwan	248	331	83	34
	Korea	565	636	72	13
	Singapore	95	149	54	57
	Belgium	214	267	53	25
	Malaysia	230	267	37	16
	Thailand	255	289	34	13
	Canada	651	680	29	4
	Ukraine	376	399	23	6
	Netherlands	293	315	22	7
	Belarus	78	94	16	20
Largest 10 relative differences	Rest of South African Customs Union	16	19	3	17
	Luxembourg	22	25	4	17
	Ireland	81	95	13	16
	Slovakia	47	53	6	14
	Mauritius	6	7	1	12
	Costa Rica	16	18	2	12
	Finland	98	108	9	10
	Estonia	21	23	2	9
	Hong Kong	136	148	12	9
	Cambodia	21	23	2	9

MRIOT – GTAP7.0 vs GTAP7.1

		MRIO carbon footprint (GTAP7.0 GHG $MtCO_2$-eq)	MRIO carbon footprint (GTAP7.1 GHG $MtCO_2$-eq)	Absolute difference (GTAP7.1 GHG $MtCO_2$-eq)	Relative difference (%)
Largest 10 absolute differences	Rest of Western Asia	1064	1016	-47	-4.5
	China	5101	5066	-35	-0.7
	Italy	794	760	-34	-4.3
	Germany	1283	1303	20	1.5
	United States of America	7898	7918	20	0.2
	Netherlands	294	312	17	5.9
	France	750	766	16	2.2
	United Kingdom	1022	1035	13	1.2
	Spain	535	545	10	1.9
	Belgium	211	204	-8	-3.7
Largest 10 relative differences	Bulgaria	61	68	7	10.6
	Finland	99	92	-7	-6.7
	Sweden	122	128	6	4.9
	Slovenia	24	25	1	4.1
	Romania	146	141	-5	-3.3
	Luxembourg	22	21	-1	-3.3
	Austria	135	138	4	2.8
	Malta	5	5	0	-2.7
	Vietnam	159	163	4	2.2
	Slovakia	47	48	1	2.1

Study Comparisons

- What causes largest differences (average)
  - 19%, Variations in environmental extensions
  - 5%, Definition of the Carbon Footprint
  - 1%, Different MRIOT
  - (average of largest 10): 23%, 20%, 3%
- We may give users the wrong impression about uncertainty
  - ***Must ensure we show results consistently***

Summary

- GTAP-MRIO
  - Robust and effective MRIOT for timely policy analysis
  - Probably not the best MRIOT that will exist
- MRIOA in the future
  - *Reflect* on what is needed, justify choices
  - Be *consistent*, but different
  - Careful model comparisons needed

Thank you

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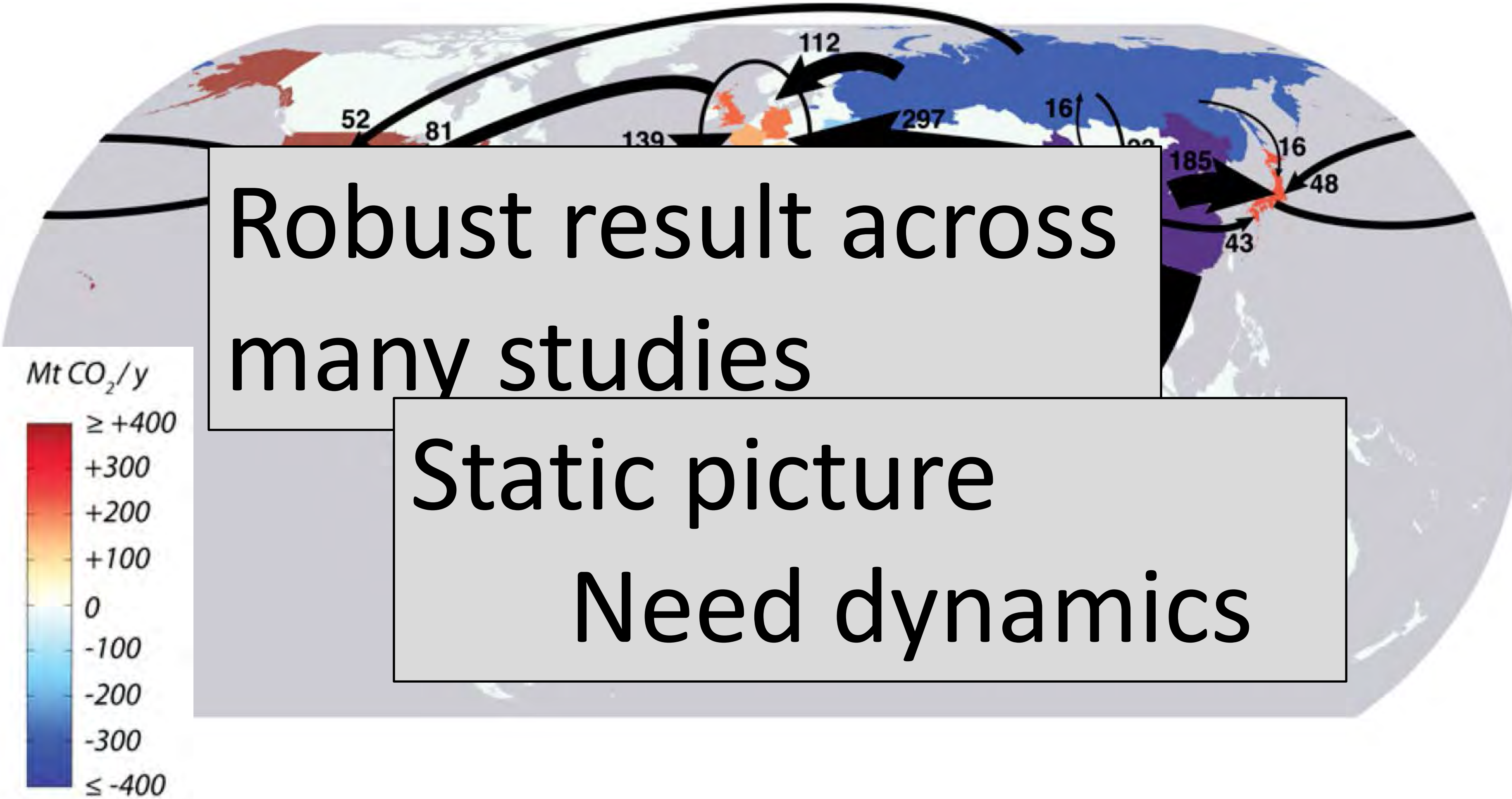
EMISSION TRANSFERS OVER TIME

Virtual embodied CO_2 emissions (2004)



Robust result across many studies

Static picture

Need dynamics

Consumption-based accounting of CO_2 emissions

Steven J. Davis[1] and Ken Caldeira

Growth in emission transfers via international trade from 1990 to 2008

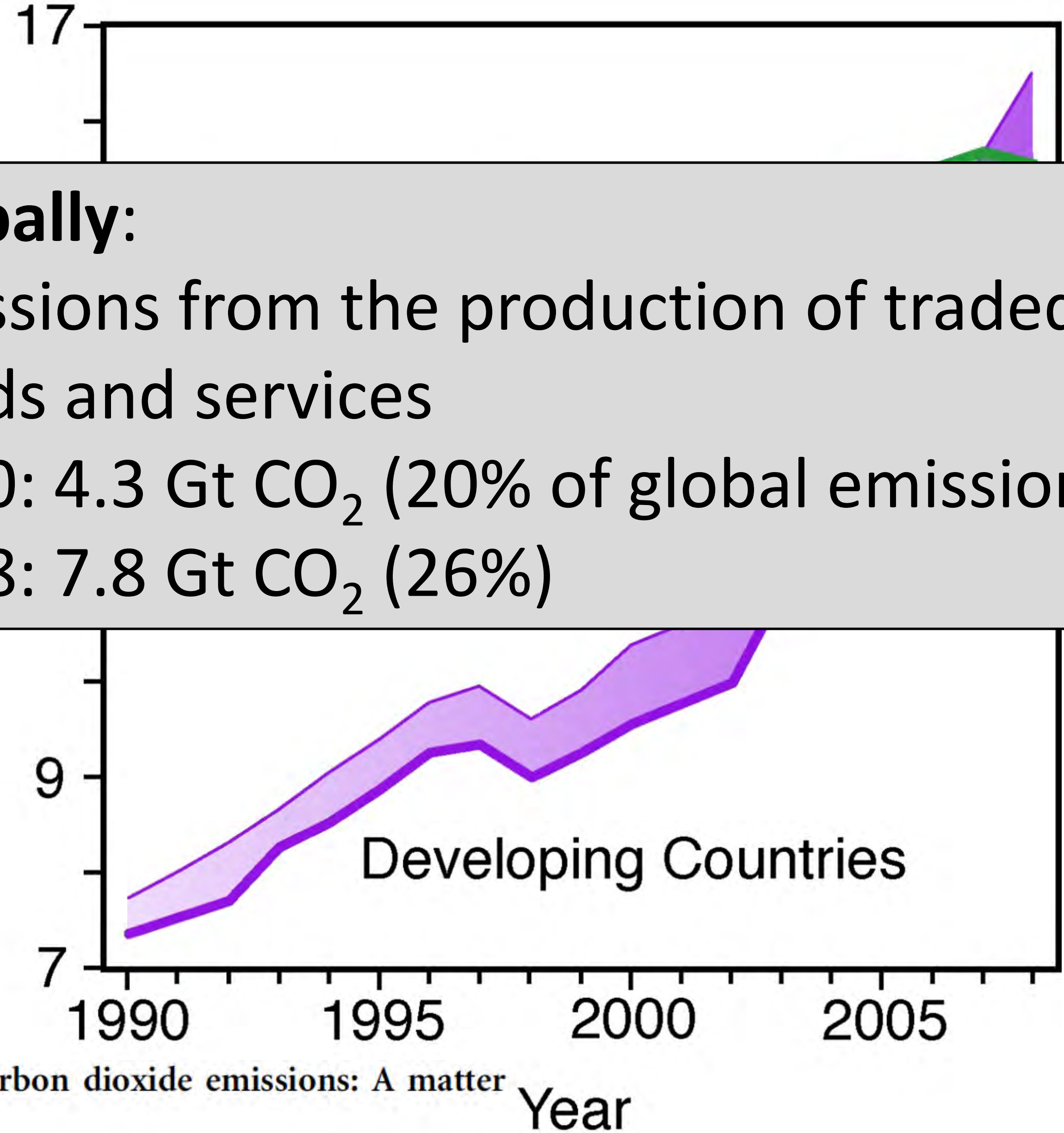
Glen P. Peters[a,1], Jan C. Minx[b,c], Christopher L. Weber[d,e], and Ottmar Edenhofer[c,f]

[a]Center for International Climate and Environmental Research–Oslo, N-0318 Oslo, Norway; [b]Department for Sustainable Engineering, and [c]Department for the Economics of Climate Change, Technical University Berlin, 10623 Berlin, Germany; [d]Science and Technology Policy Institute, Washington, DC 20010; [e]Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA 15213; and [f]Potsdam Institute for Climate Impact Research, D-14412 Potsdam, Germany

PNAS

- World split into 113 countries and region each with 57 sectors
- Annex B (developed) versus non-Annex B (developing)
- 1990 to 2008
- Focus on net emission transfer (exports minus imports)

Consumption-based CO_2 Emissions



Globally:

Emissions from the production of traded goods and services

1990: 4.3 Gt CO_2 (20% of global emissions)

2008: 7.8 Gt CO_2 (26%)

PNAS Accounting for carbon dioxide emissions: A matter of time

Ken Caldeira[1] and Steven J. Davis
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PNAS

Accounting for carbon dioxide emissions: A matter of time

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Carbon dioxide emissions in one country can support consumption of goods and services in another country; countries and their CO_2 emissions are linked together by international trade. The study of CO_2 emissions embodied in international trade was largely opened up by Peters and Hertwich (1). In PNAS, Peters et al. (2) introduce a dimension into this field of study, and that dimension is time. It is not often that one team of researchers has done so much to introduce a field of inquiry and then expand it so rapidly, giving us insights into the challenges and potential solutions to the energy/carbon/climate problem we all face.

On any typical day, we engage in a wide range of activities that are supported by CO_2 emissions, either directly or indirectly. When we drive our cars to work, CO_2 comes out of the tailpipe—a waste product resulting from the reaction of gasoline with atmospheric oxygen inside of an internal combustion engine. So, how much CO_2 was released to the atmosphere to get us to work this morning? Counting just the CO_2 that comes out of the tailpipe would fail to consider the fact that CO_2 was emitted to extract, refine, and transport that gasoline to us. The automobile is composed of steel and rubber, aluminum and plastic; CO_2 was released to supply the energy needed to manufacture each of these materials. Furthermore, the factories that produced the automobile had machines of various sorts, and the energy it took to make these machines likely produced CO_2 emissions as well. Furthermore, the workers in factories that made all of these things may have driven cars to get themselves to work. What part of their CO_2 emissions was emitted to facilitate our morning commute?

Very quickly, we see that nothing exists in isolation, and that to understand how much CO_2 emission can be related to any particular action, we must have a reasonable accounting system that allocates total emissions to specific actions. Accounting systems are not facts of nature, but conventions constructed by people. (How much of the factory worker's CO_2 emission while commuting to work should be attributed to our consumptive pleasure versus their own consumptive pleasure? How much of the emissions from the authors' morning commute should be attributed to you, the reader?)

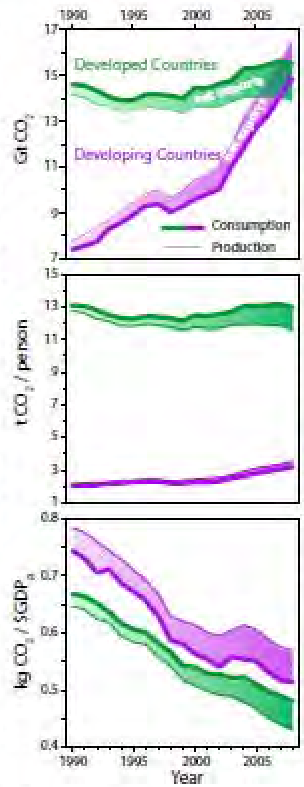

Fig. 1. Consumption-based and production-based accounting of CO_2 emissions by Peters et al. (2), divided into industrialized and industrializing countries (detailed in the text). (*Top*) CO_2 emissions to support consumption in developed countries exceed CO_2 emissions to support consumption in developing countries, despite the fact that more CO_2 emissions are produced within the territory of developing countries. (*Middle*) On a per-capita basis, there is great disparity in consumption emissions between developed and developing countries. (*Bottom*) Consideration of a consumption-based perspective produces less of a difference in carbon intensity of economic activity (adjusted for purchasing power parity) between developed and developing countries.

Accounting systems can be more or less useful for various purposes, but they are not right or wrong. If we want to attribute CO_2 emissions to the consumption of particular goods or services, we must have an accounting system that conforms with our intuitions about how responsibility should be shared among participants in complex systems.

We do not have enough information about the world to map out the complex web that links specific goods and services with specific CO_2 emissions, but enough data do exist to map out these webs for broad product categories at the level of countries (or collections of small countries). At this level of detail, we can ask questions like: How much of the consumption in the United States was supported by CO_2 emitted in other countries? Peters and colleagues have been pioneers in the effort to quantify these international transfers, often referred to as "carbon emissions embodied in international trade." It is important to distinguish between carbon embodied in international trade (i.e., CO_2 that was released to the atmosphere to support the production of goods and services that are internationally traded) from actual carbon in international trade, such as is found in internationally traded fossil fuels, foodstuffs, or plastics.

Peters and Hertwich (1) and Hertwich and Peters (3) described reasonable accounting methodologies that others, including ourselves, have applied to static cases, such as analysis of a particular year. For example, we used their methods to estimate that, in 2004, 19% of the CO_2 emitted to support production of goods and services consumed in the United States was emitted outside US territorial borders, whereas 28% of China's territorial CO_2 emissions supported production of goods and services consumed outside of China (4). Furthermore, some emissions in the United States supported consumption in other countries, while emissions in other countries helped support consumption in China.

Author contributions: K.C. and S.J.D. wrote the paper.
The authors declare no conflict of interest.
See companion article on page 8903.
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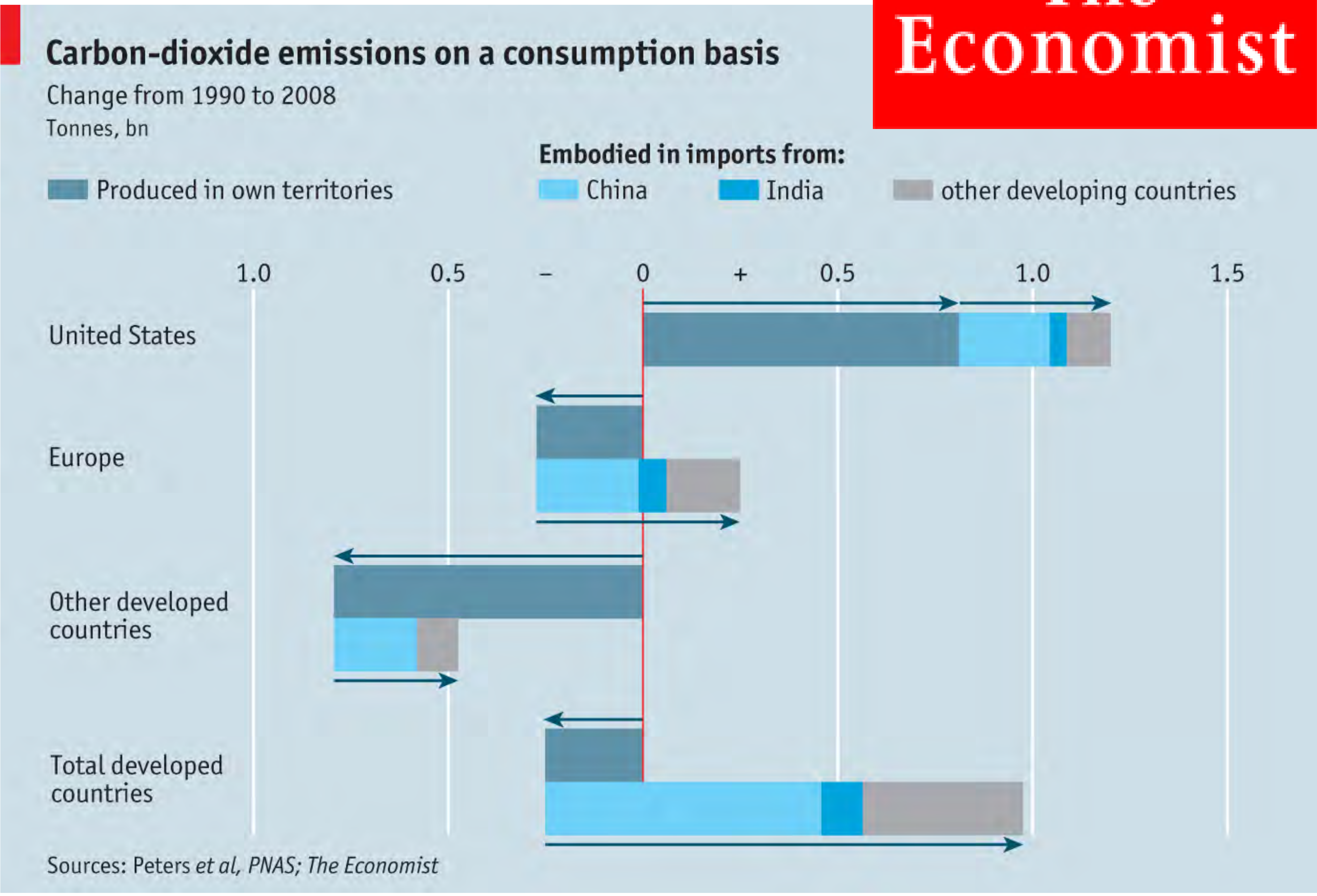

Carbon-dioxide emissions on a consumption basis
Change from 1990 to 2008
Tonnes, bn
Embodied in imports from:
Produced in own territories
China
India
other developing countries
1.0
0.5
–
0
+
0.5
1.0
1.5
United States
Europe
Other developed countries
Total developed countries
Sources: Peters *et al, PNAS; The Economist*

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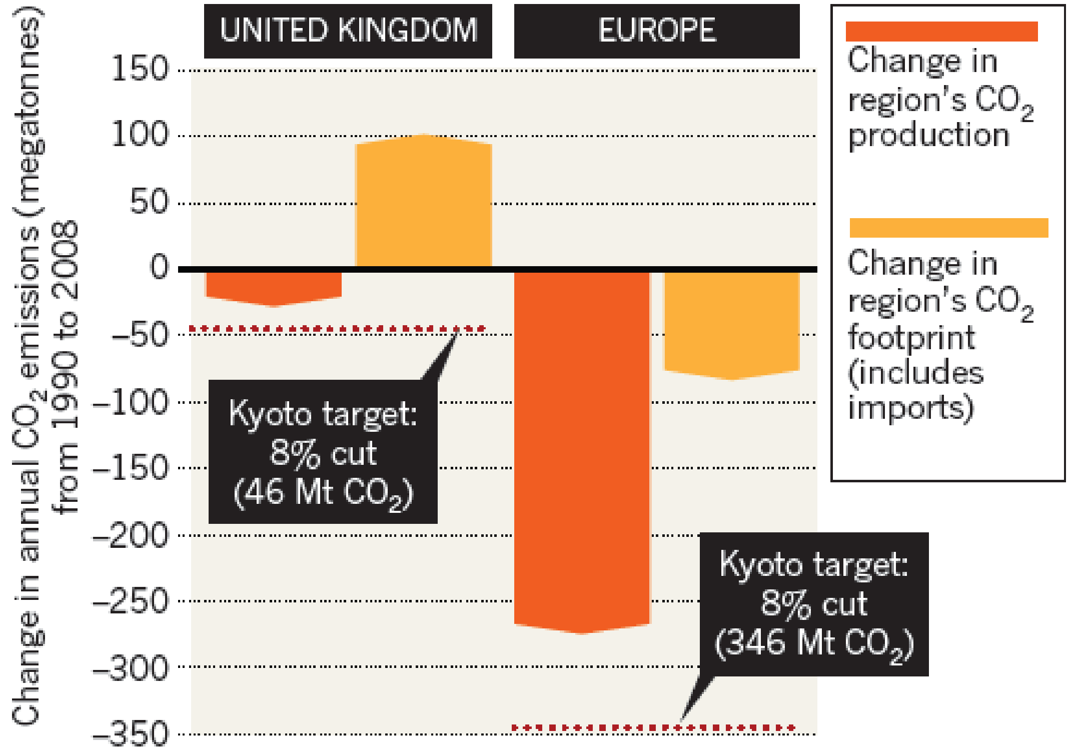
TREND WATCH

Developed nations are responsible for more carbon dioxide emissions than they produce, because they import goods made in other countries. A study of emissions from 113 countries for 1990 to 2008 (G. P. Peters *et al. Proc. Natl Acad. Sci. USA* doi:10.1073/pnas.1006388108; 2011) shows that developed countries (as classed under the Kyoto Protocol) increased their CO_2 footprint by 7% — even though they reported 2% production cuts. The chart shows the effect for the United Kingdom and Europe.

HOW TRADE AFFECTS CARBON FOOTPRINTS

Rich regions have achieved cuts in carbon emissions since 1990, but largely by importing more goods from elsewhere.



in grasslands, which have some of the ... functions of different microbial groups ... *Jennifer M. Talbot and Kathleen K. Treseder are*

nature climate change

results indicate that modifying climate models by incorporating the diverse

validate Orwin and colleagues' model at a regional scale.

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POLICY

Trade's growing footprint

The production of traded goods accounts for a significant proportion of global greenhouse-gas emissions. Now analysis reveals that emissions embodied in imports from developing countries have out-stripped emission reductions made by developed countries at home over the past 20 years.

Carolyn Fischer

The question of the burden that different countries should bear in reducing greenhouse-gas emissions is at the heart of international negotiations to tackle climate change. The 1992 *United Nations Framework Convention on Climate Change* established the principle of 'common but differentiated responsibilities', acknowledging that developed countries bear more responsibility than developing countries for historical emissions, and that emissions from developing countries will need to grow to facilitate their development. Shortly after the convention was adopted, the World Trade Organization was established, enshrining rules and obligations for liberalized trade. Since then, global trade has expanded and shifted, with emerging economies becoming major exporters of manufactured goods, rather than just raw materials and agricultural commodities[1]. Writing in *Proceedings of the National Academy of Sciences*, Peters and colleagues[2] show that these changes make it even more difficult to answer the question of who should be responsible for reducing greenhouse-gas emissions — not least because emissions embodied in imports from developing countries over the past 20 years exceed the emission reductions that developed countries have made within their own territories.

Under the 1997 Kyoto Protocol, developed countries agreed to legally binding emission-reduction targets for 2012. These commitments apply only to greenhouse-gas emissions produced within each country's own territories. By this 'territorial' accounting system, developed countries have stabilized their carbon dioxide emissions since 1990, while emissions from developing countries have doubled[2]. However, this system does not account for the flows of trade between countries and thus overlooks the fact that developed countries are net importers of emissions, while emerging economies are net exporters[3,4].

Peters and colleagues[2] identify important trends in the role that international trade has played in emissions growth at global, regional and country scales. Using a time series of global trade data, they calculated net emission transfers between almost 100 different countries — that is, the emissions generated in a country to produce exported goods and services minus the emissions that are generated elsewhere to produce the goods and services that it imports. Adjusting each country's territorial emissions by this amount, they created inventories that reflect the emissions associated with consumption in each country (Fig. 1).

The analysis shows that net emission transfers from developing to developed countries have been growing steadily, at a average rate of 17% per year. Furthermor for developed countries as a whole, these transfers exceed the reductions in territorial emissions achieved since 1990. Overall, growth in emission transfers to developed countries through internation trade equates to 14% of the growth in global carbon dioxide emissions since 1990. China has played a striking role in these trends: emissions associated with imports from China accounted for 75% of the growth in developed countries' consumption-based emissions. Moreover, Chinese emissions accounted for 55% of the growth in global carbon dioxide emissions from 1990 to 2008, with one-third of this contribution due to exports.

Analysis by sector reveals that energy-intensive industries such as cement and steel production, which are often targeted in climate policies, are not the main source of 'carbon leakage' from developed to developing countries. Trade in these sectors has grown in both directions since 1990, leaving net emission transfers greater in non-energy-intensive industries, such as manufacture of equipment and electronics. Nor are developed countries' climate policies likely to explain much of the growth in carbon leakage over the past two decades, because they began in earnest only recently. Rather, Peters *et al.*[2] have identified more general trends in emission transfers that are probably driven by a range of socio-economic factors.

The methods used by Peters *et al.*[2] are well-established. However, one caveat to their analysis is that it relies on data that are aggregated by region and by sector. The school of thought known as 'new trade theory' indicates that firms that export goods tend to be more productive than those that produce goods only for domestic consumption[5]. If exporters are indeed less energy intensive than average for a given sector, calculations based on aggregated data will over-estimate emission transfers.

Peters *et al.* downplay the policy implications of their work, but other authors have called for emission transfers to be accounted for in the distribution of post-Kyoto abatement burdens[3]. However, asking developed countries to achieve deeper reductions in their territorial emissions while emissions from emerging economies remain largely unconstrained risks exacerbating the problem of carbon leakage, which would undermine domestic support for stringent regulation of emissions. Developed countries will also resist being made to take responsibility for emissions they cannot control.

Ensuring that consumers in developed countries bear the full cost of the goods they consume, including imported emissions, would require implementation of border carbon adjustments — compliance payments levied on goods imported from countries that do not account for the cost of carbon by countries that do. In theory, careful implementation of border adjustments could reduce carbon leakage and improve the cost-effectiveness of sub-global carbon-pricing programmes[6,7]. Yet such proposals may not be compatible with trade-law obligations[6]. They also raise vehement objections from emerging economies, owing to the anticipated effect on their prospects for growth (which may already be limited by emission constraints imposed on their trading partners)[7].

Recent analysis indicates that implementing regulations or agreements to reduce emissions across specific sectors in developing countries could achieve emission reductions at a much lower cost than trade measures[8]. Thus, it seems that the aim of reducing global emissions would be better served by pursuing common policies in key traded sectors while using other means — such as transferring emission-reduction technologies and financial aid — to differentiate the economic burden among countries.

The crux of the problem explored by Peters *et al.*[2] is that emissions embodied in international trade have grown significantly over the past 20 years, arguably driven by market forces unrelated to climate policy. The trade that these emissions reflect has been a tremendous engine for economic development that has benefited developing and developed countries alike — but the negative consequences that embodied emissions bring will also be borne by both parties. Agreeing on ways to reduce these emissions will be difficult — but the real challenge will be taking responsibility, not assigning it.

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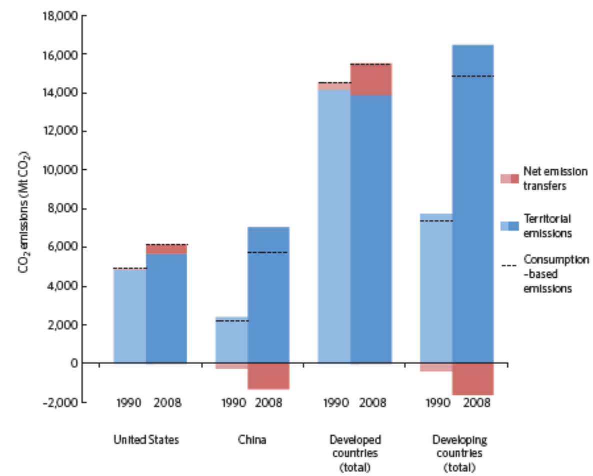

Figure 1 | Emissions embodied in international trade. The chart shows territorial emissions (blue bars), net emission transfers from international trade (red bars), and consumption-based emissions (dotted lines) in 1990 and 2008 for developed and developing countries and the two largest single emitters, the United States and China, calculated by Peters and colleagues[2]. Negative values for emission transfers indicate net export of emissions, whereas positive values reflect net import. Consumption-based emissions are the balance between territorial emissions and net transfers. Although China is the largest emitter on a production basis as of 2008, on a consumption basis the United States remains ahead. Similarly, emissions from developed countries exceed those from developing countries on a consumption basis.

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Carbon Management (2011) 2(3), 219–223

News

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Recent report on international imports and exports sheds new light on source of carbon emissions

A team of international researchers have compiled a global trade-linked database of CO_2 emissions, allowing for the first time a detailed analysis of the impact of international trade on the development of individual countries' carbon emissions

Authors of a new study, published in the *Proceedings of the National Academy of Sciences* compiled a global trade-linked database of CO_2 emissions, comprising of data from 1990 to 2008, for 57 economic sectors in 113 countries. It is believed this data, for the first time will allow, a detailed analysis of the impact of international trade on the development of individual countries emissions over time.

An increasing amount of global CO_2 emissions is being attributed to the production of internationally traded goods and services, with the report finding that 26% of global emissions are coming from producing goods for trade. However, emissions from production processes are allocated to the producing country, which means that the consuming country is entirely unaccountable for these emissions. As such, consuming countries can increase their consumption, or carbon footprint, whilst keeping their officially reported emissions stable.

Many developed countries have reported stable emission levels, thanks in part to the accounting rules established under the UNFCCC, which requires countries to only report territorial emissions. According to the report, industrialized countries are currently meeting their emission targets by shifting emissions to the developing world. This allows industrialized countries to meet climate protection targets with comparatively less effort, despite growing their consumption levels.

Glen Peters at the Center for International Climate and Environmental Research – Oslo (CICERO), lead author of the study, commented that "a key explanation for this finding is that increased imports to rich countries have led to increased production and emissions in developing countries". He continued, "…international trade has enabled much needed economic development in emerging economies, but at the same time, many rich countries have benefited as they increased consumption without increasing their reported territorial emissions".

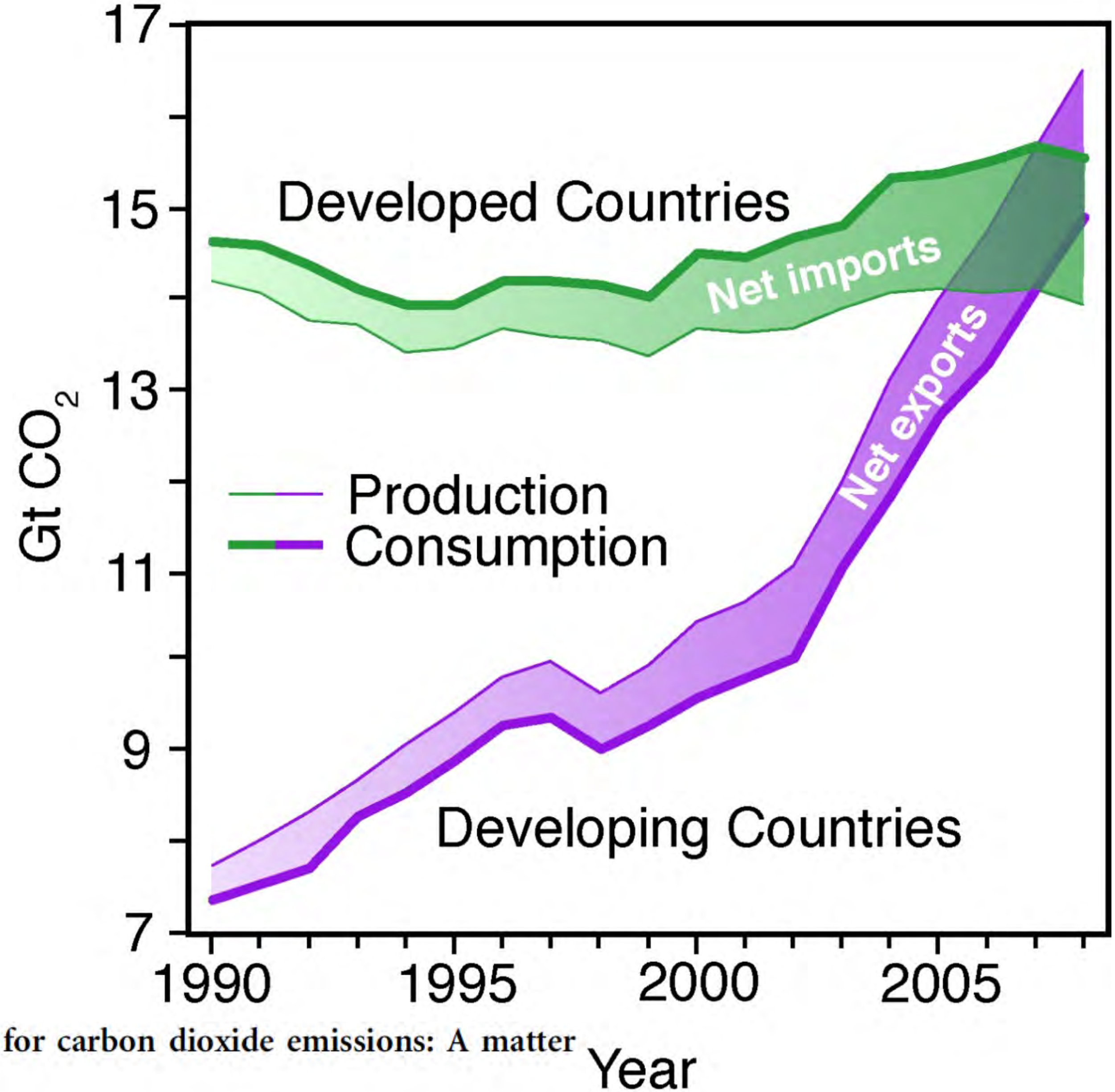
The report found that in 2008, the increase in emissions in developing countries compared to industrialized country consumption was five-times greater than the savings in industrialized countries. Jan Minx, from the Departments Economics of Climate Change and Sustainable Engineering at Technical University Berlin explained that "through their consumption most industrialized countries contributed more to emission increases in developing countries than they cut emissions at home". Speaking to *Carbon Management*, Peters said "our results suggest that adjustments to current climate policies could be more effective at reducing global emissions". He spoke of the aims of the research, stating that "our ultimate objective should be a climate policy with global coverage, but before this objective is met, we need a system in place to ensure that non-climate policies, such as trade policies, do not offset the gains made in climate policy".

When asked by *Carbon Management* about future plans for work in this area, Peters said "more detailed studies understanding the key drivers for change, both globally and regionally, are needed. Our work can be extended to cover other long-lived GHGs (e.g., methane and nitrous oxide), emissions from land-use change, and also short-lived components that have an effect on climate". He continued, "more forward-looking studies are needed, however, to determine how international trade will respond, not only to climate policy, but also to other policies which effect international trade".

Source: Peters GP, Minx JC, Weber CL, Edenhofer O. Growth in emission transfers via international trade from 1990 to 2008. Proc Natl Acad Sci DOI: [illegible] (2011) (Epub ahead of print).

10.4155/CMT.11.29 © 2011 Future Science Ltd

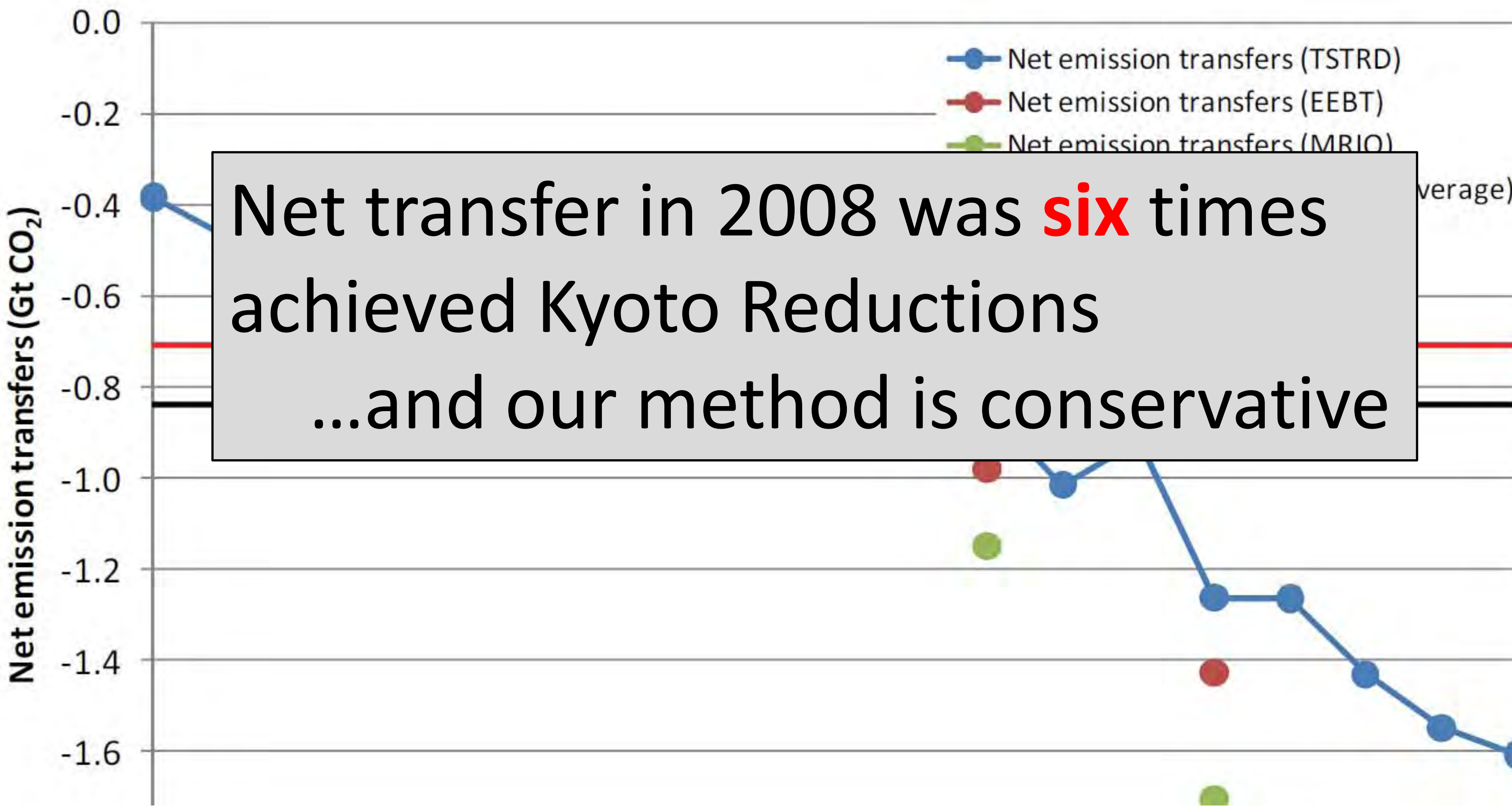
Consumption-based CO_2 Emissions



Accounting for carbon dioxide emissions: A matter of time

Ken Caldeira[1] and Steven J. Davis
Department of Global Ecology, Carnegie Institution, Stanford, CA 94305

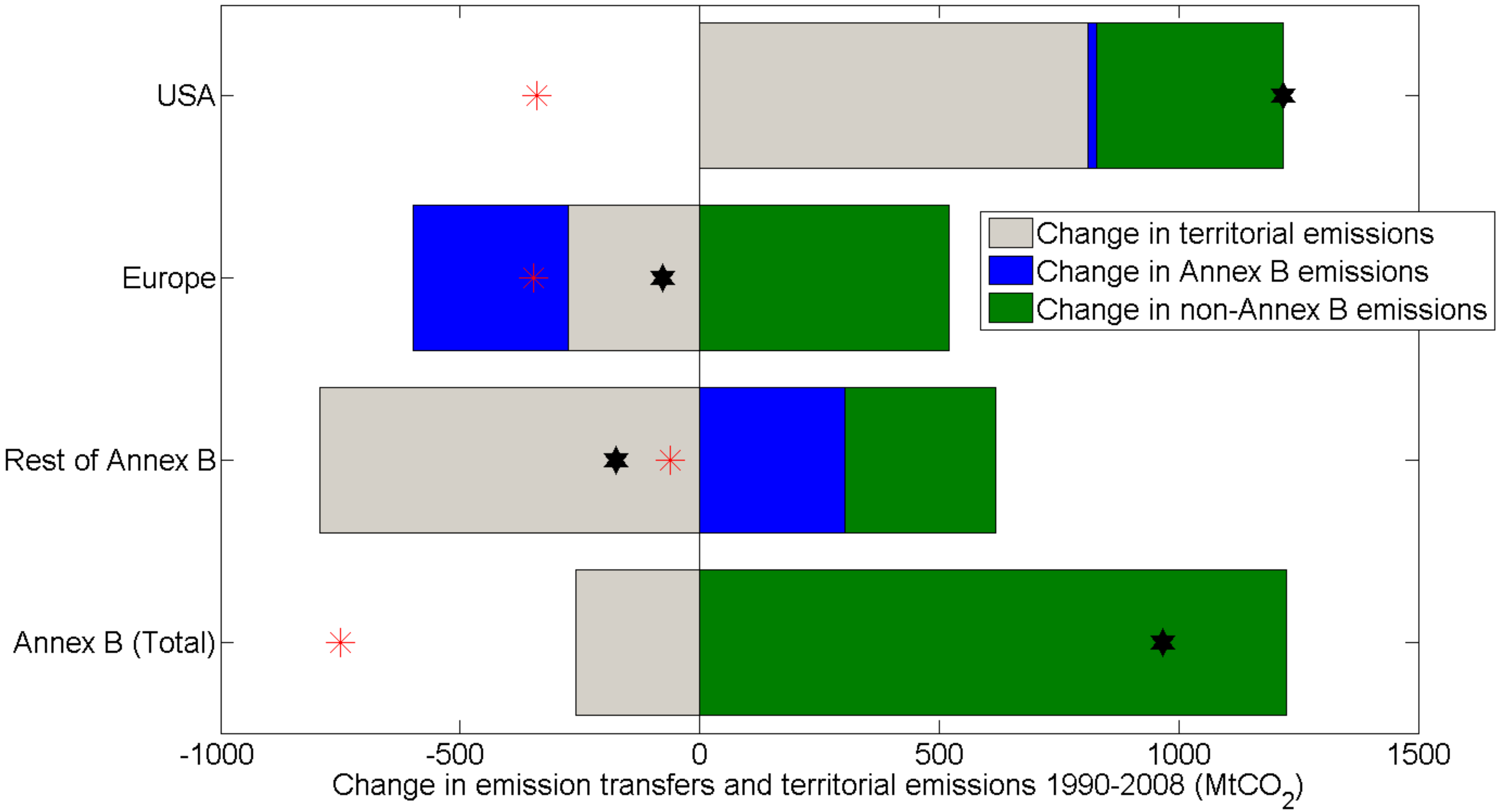
Changes offset Kyoto reductions

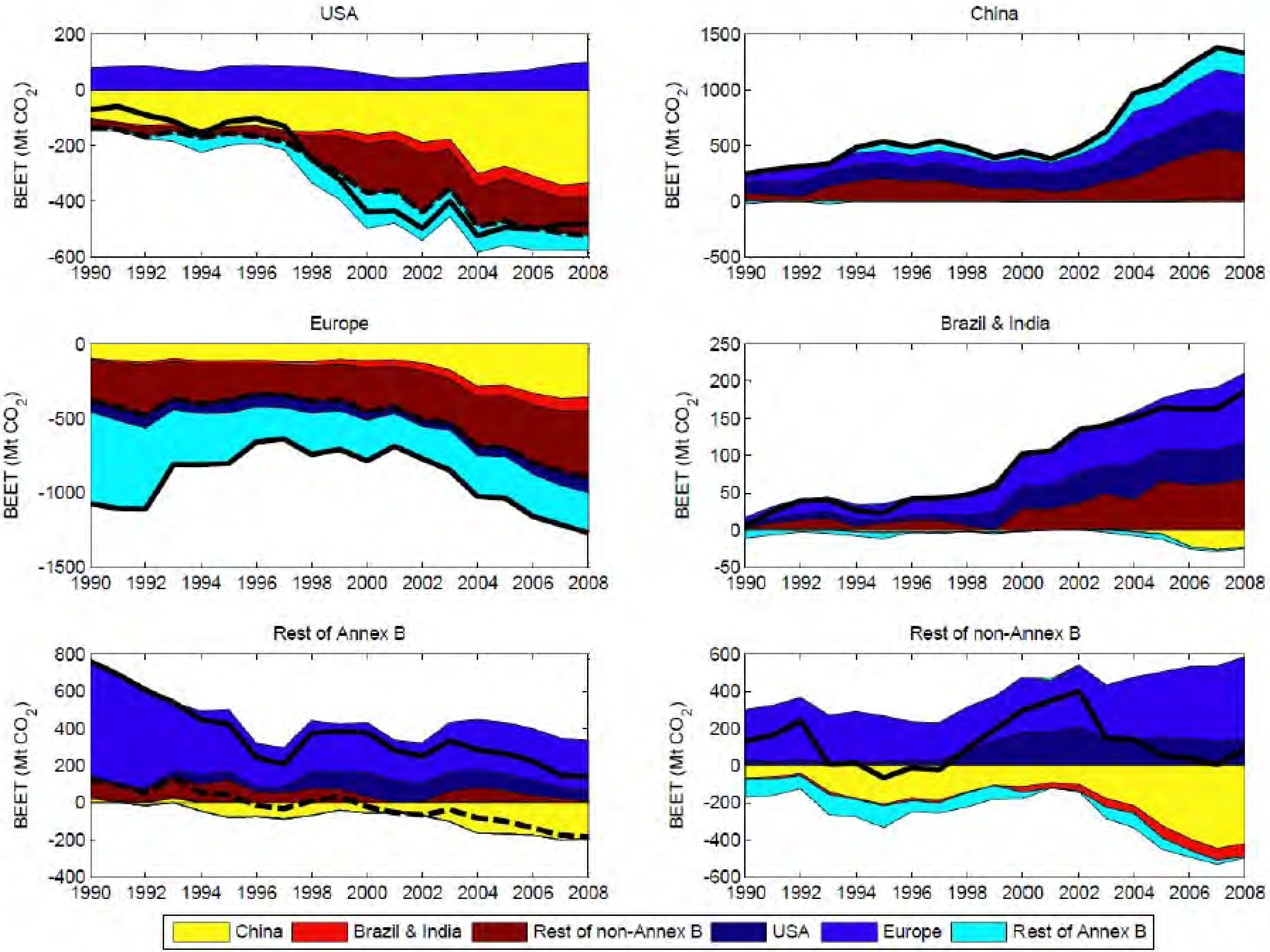


Net transfer in 2008 was **six** times achieved Kyoto Reductions

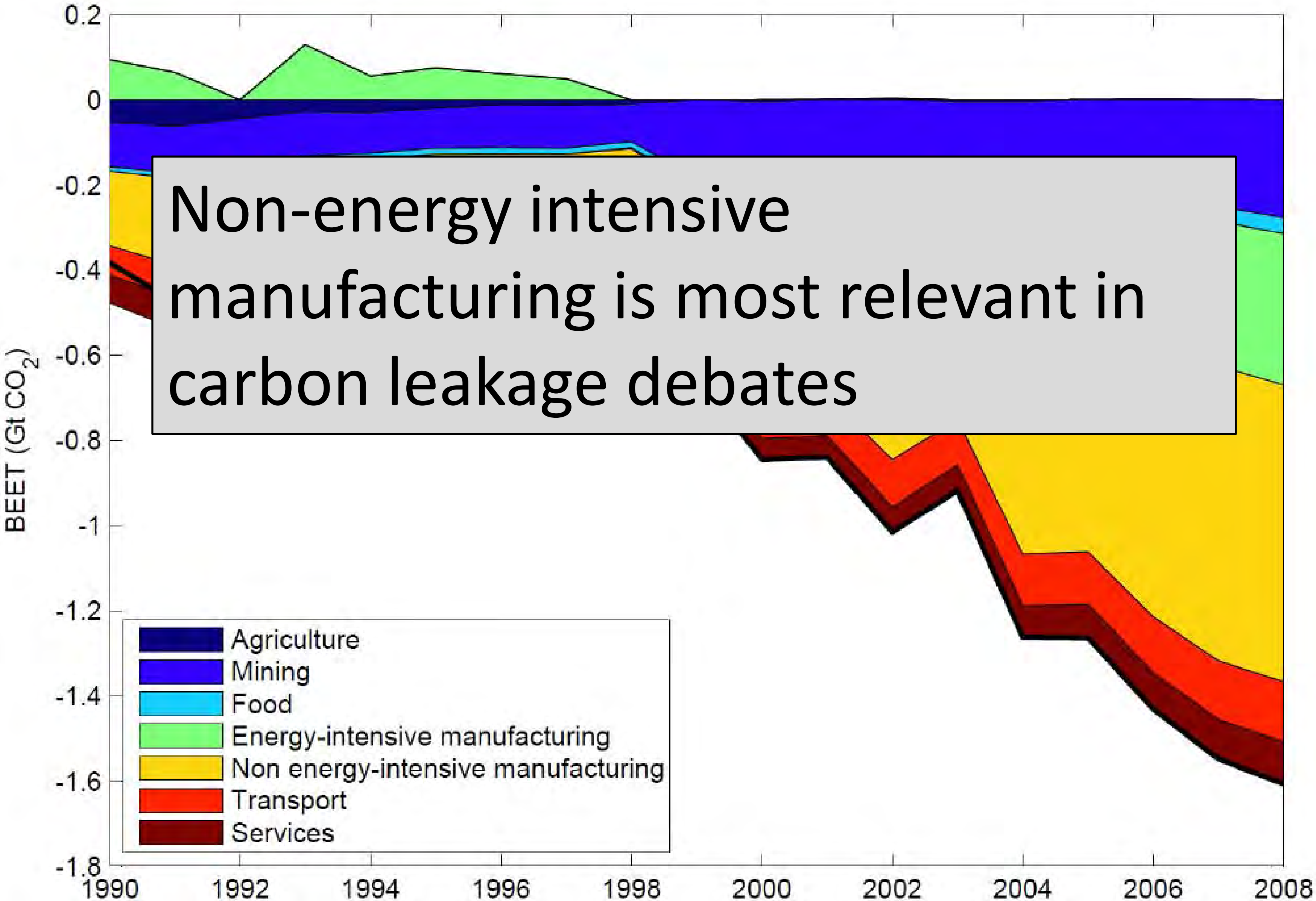
…and our method is conservative

Aggregated offsets




USA
China
Europe
Brazil & India
Rest of Annex B
Rest of non-Annex B
BEET (Mt CO_2)
200
0
-200
-400
-600
1500
1000
500
-500
-1000
-1500
250
150
100
50
-50
800
600
400
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
China
Brazil & India
Rest of non-Annex B
USA
Europe
Rest of Annex B

Sector Detail



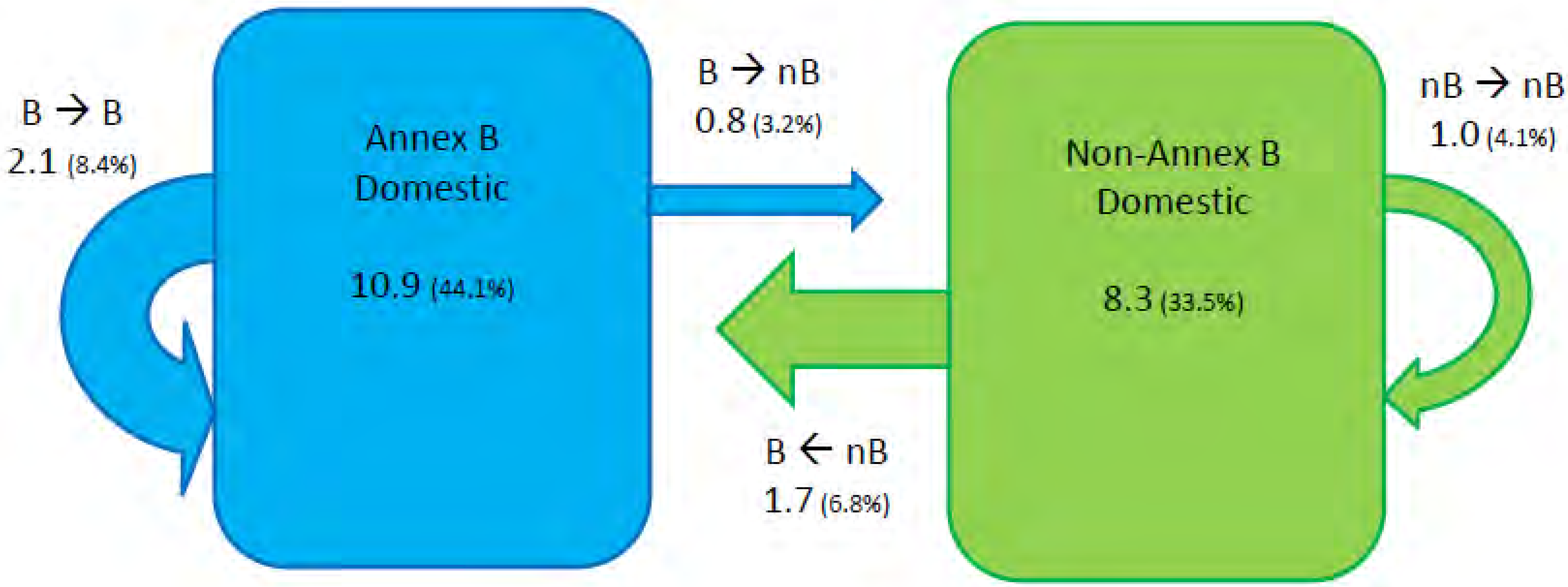
Non-energy intensive manufacturing is most relevant in carbon leakage debates

°C

TSTRD

Kyoto Carbon Cycle (1990-2008)

Cumulative Gt CO_2/year (% global)



Annex B
Production: 13.7 (55.6%)
Consumption: 14.7 (59.3%)

Global
24.7

non-Annex B
Production: 11.0 (44.4%)
Consumption: 10.1 (40.7%)