Carbon Accounts, Value Chains, and International Trade

Octavio Fernández-Amador, Joseph F. Francois,

Doris Oberdabernig, and Patrick Tomberger

Joseph Francois,
WTI, CEPR, CES-ifo

Vienna, February 2018

world trade institute

UNIVERSITÄT BERN

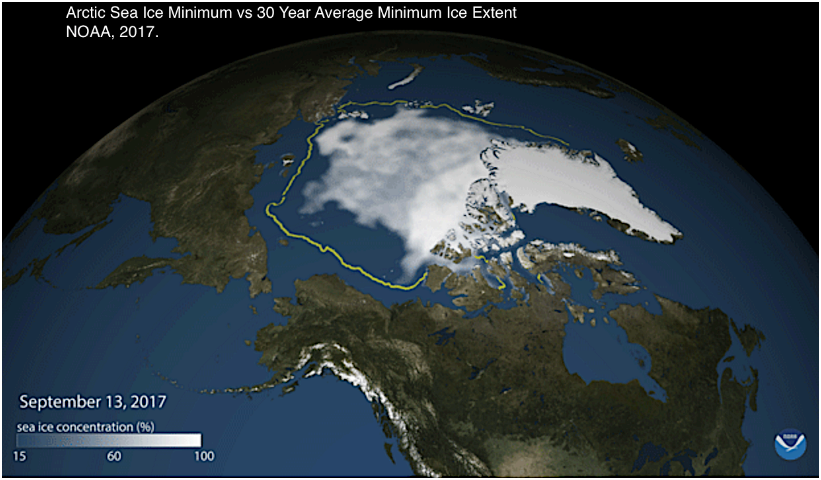
Outline

- Motivation
  - the case for carbon management
  - trade, value chains, and the challenge of carbon accounting
  - some discussion beyond carbon (resources in general)
- Methodology and Data
- Results and Descriptives (Based on several papers, published and ongoing, and a large scale SNSF project)
- Conclusion

Kyoto failure, Paris reboot, attribution of responsibility

- Demand for goods & services is a significant global driver of emissions
- A major problem of international environmental agreements concerns the distribution of responsibility & aligning incentives with objectives
- Global pollutants like CO_2 and CH_4 present a problem of externality effects: Need to include developing regions (China) to effectively control atmospheric carbon.
- International trade connects demands & supplies globally, and transmits costs from pollution cutbacks. *Critically, it also makes the national inventory approach less and less tenable.*
- Consumption- and embodied production-based emission inventories can supplement production-based information to for negotiation & monitoring of multilateral commitments (e.g. Paris Agreement). They may also allow new instruments, while requiring changes in commercial treaties.

Relevance: Arctic Sea Ice Extent observation (2017 and 30 year average)



Source: NOAA GFDL model and the Arctic Institute (2017).

Relevance: Arctic Sea Ice and Trade

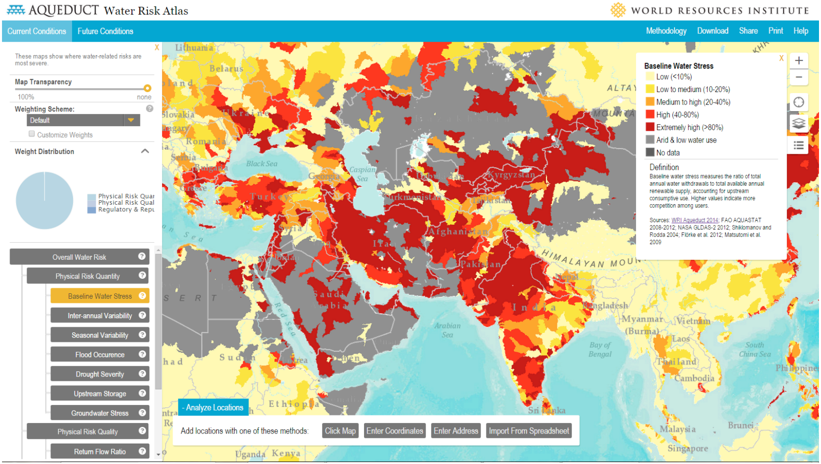
Fig. 1. *The Northern Sea Route and Southern Sea Route Shipping Routes*
Vote. Colour figure can be viewed at wileyonlinelibrary.com.

Source: Bekkers, Francois, and Rojas-Romagosa, *Economic Journal* 2017.

Relevance: The Evolution of the Rhone glacier from 1850 until today.

Source: VAW-ETHZ.

Relevance: Other Resource Challenges (water links to conflict, trade, and migration).



Water levels under stress.

Why should we talk about Methane, and not just CO_2?

CH_4 is the second major contributor to anthropogenic global warming

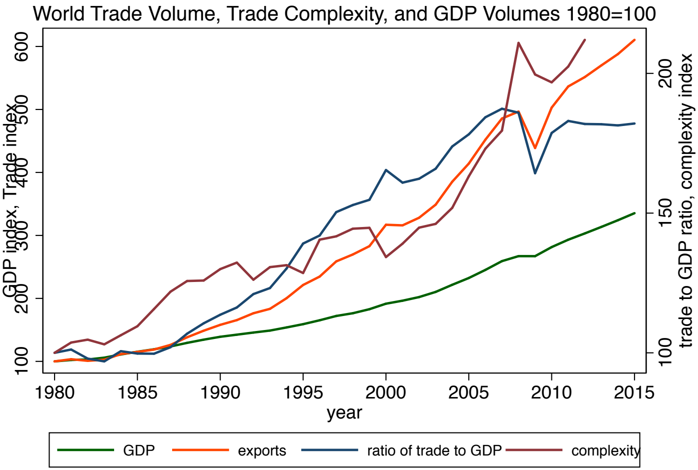
- 20% warming from GHGs since pre-industrial time
- High warming potential, notably in the beginning of its atmospheric life
- Implies contemporaneous impact of human behavior on warming
- Very heterogeneous processes generating CH_4e

	CH_4 (CO_2e, 100y)		**CH_4** (CO_2e, 20y)		**CO_2**
	Mt.	% of CO_2	Mt.	% of CO_2	Mt.
1997	5862.41	25.82	20099.68	88.54	22701.79
2001	5999.47	26.02	20569.60	89.22	23054.30
2004	6410.75	24.28	21979.73	83.25	26403.22
2007	6800.65	23.35	23316.50	80.07	29121.03
2011	7313.50	23.61	25074.85	80.96	30971.11

$\Rightarrow$ Quantitatively important, particularly in the short term; 25% increase (1997–2011)

Challenges to national inventories as a benchmark:

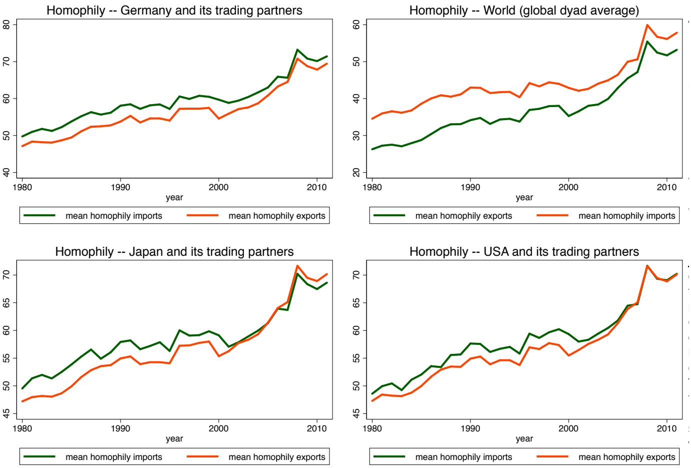
The volume and complexity of world trade



source: IMF WEO database 2015 and UN COMTRADE database.

Challenges to national inventories as a benchmark:

The volume and complexity of world trade



note: based on UN COMTRADE database. See Egger, Francois, Nelson (2015).

What we are doing

Observation

- There is a gap between consumption- and production-based concept of emissions, subject to different driving factors
- Resolving this gap requires better integration of MRIO analysis with carbon and resource accounting

What we do, and what we are doing

- We develop a panel of 78 countries/regions: 1997-2014
- Trace net flows of embodied carbon, extension to other resources
- Distinguish production, consumption & embodied production inventories
- Mapping trends into composition and efficiency effects 1997-2014
- Projection modelling under SSPs to identify stress points looking forward
- Joint legal/economic analysis of alternative instruments e.g. CAT (Carbon Added Tax) instead of producer and border taxes

Literature related to this work program

Value chains and MRIO structure of trade

- Amador, J., Cabral, S., (survey) 2017.
- Baldwin, R., L—pez-Gonz‡lez, J. 2015, Baldwin 2014.
- Egger, Francois, Nelson 2017
- Koopman, Wang, and Wei. 2014

Carbon accounts, leakage, & policy: numerics, econometrics, accounting

- Zhong, Haizhong, Fang, Gao, and Dong 2016 (the global energy network)
- Böhringer, Lange, and Rutherford 2014 (emission pricing with leakages)
- Peters and Hertwich 2008a,b Peters, G.P., Minx, J.C., Weber, C.L., Edenhofer, O., 2011, (cross section inventories)
- entire Kyoto and Kuznets curve literature (Aichele Felbermayer, 2015)
- MRIO-based panels: Fernandez-Amador, Francois, Oberdabernig*, Tomberger (2016,2017*).

Accounting principles and method

Calculations of production-based emissions:

- 6 energy commodities (Mtoe) of GTAP energy volume database.
  - GTAP provides deeper country coverage. from 2001-2014 we can get roughly 100+ countries vs roughly 45 in GTAP)
  - GTAP includes representation of international transport and associated emissions (needs to be improved)
- Applying IPCC 1996 guidelines on GTAP 5,6, 8, 9, 10
- Extended FAO and EDGAR accounts on methane, also applied to GTAP 5-10

Tracing consumption by multi-region I-O methodology

- Accounting for global supply chain linkages, flows of intermediates
- Trade data (bilateral trade and I-O, SAM) allow us to trace inventories

We end up with the carbon footprint in consumption C_{it}

$$C_{it} = D_{it} + NEET_{it}$$

The MRIO I-O table

The world I-O table collects all bilateral inter-sector demand linkages

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1m} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2m} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & A_{m3} & \cdots & A_{mm} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} + \sum_r \begin{pmatrix} y_{r1} \\ y_{r2} \\ y_{r3} \\ \vdots \\ y_{rm} \end{pmatrix}$$

$A_{ij,s \times s}$:= normalized bilateral trade I-O table of intermediates produced in country i used in country j including domestic use.

Tracing carbon to final consumption

$x_n = Ax_n + y_n$

output in country n equals intermediate inputs and all-i final goods traded

$y_n = (I - A)^{-1} x_n$ Leontief inverse $(I - A)^{-1}$

collects direct and indirect requirements of intermediates to produce a unit of output for each sector in each country

$e = (e_1, \ldots, e_i, \ldots, e_N)$

collects all the sector emission intensities in country i

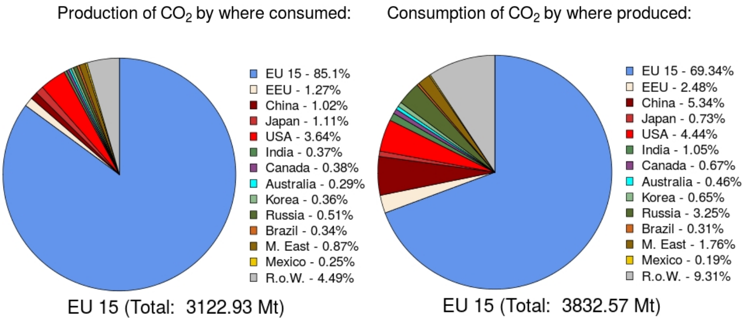
$c = (c_1, \ldots, c_i, \ldots, c_N)$

collects consumption of final goods per sector in country i

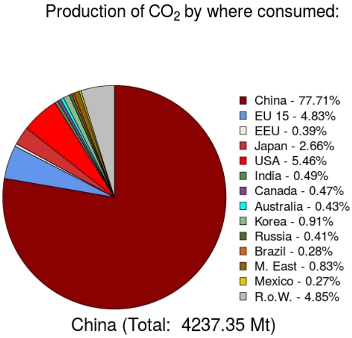
$F^c = e(I - B)^{-1} c$, $F^x = e(I - B)^{-1} x$

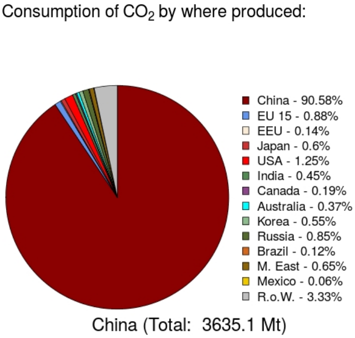
traces total carbon emissions to final consumption for each sector in each country

EU CO_2 production and consumption by source: 1997-2011 averages

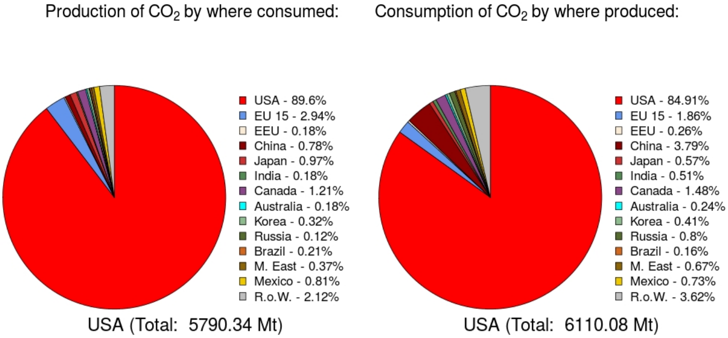


China CO_2 production and consumption by source: 1997-2011 averages

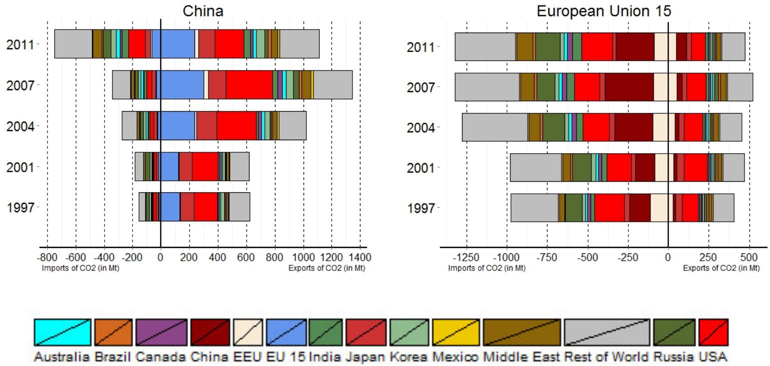




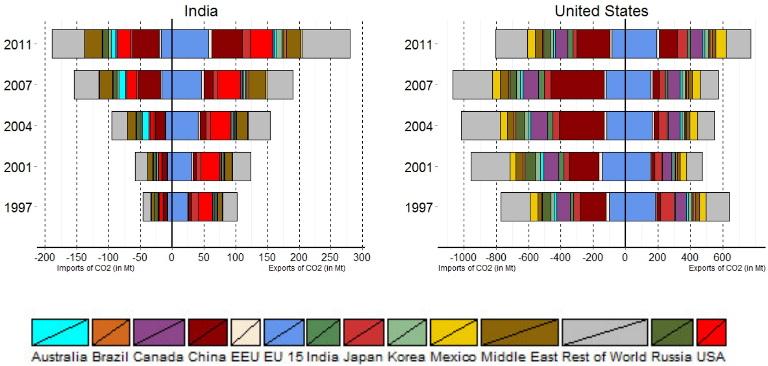
USA CO_2 production and consumption by source: 1997-2011 averages



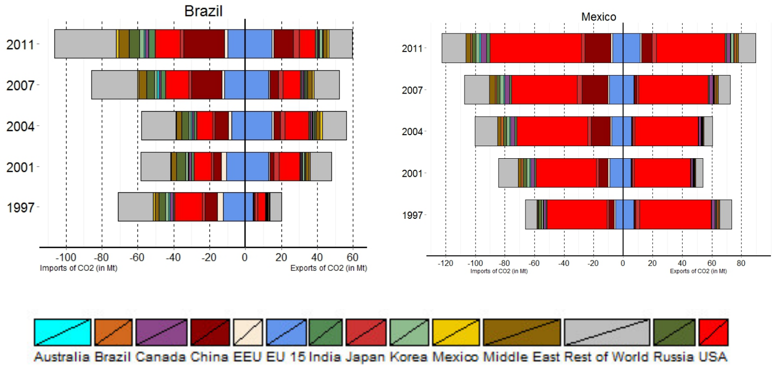
Carbon emissions embodied in international trade: China and EU15



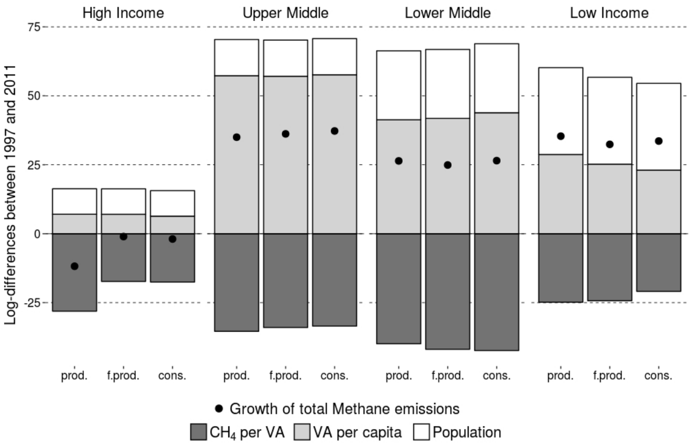
Carbon emissions embodied in international trade: India and USA



Carbon emissions embodied in international trade: Brazil and Mexico



Kaya identity; Change in the components of CH_4e (1997–2011)



Econometric model of CH_4 emissions - threshold:

Threshold rather than polynomial regressions to capture non-linearities:

- Threshold model (Hansen, 1996, 1999, 2000 and Caner and Hansen, 2004):

$$\underbrace{E_{it}}_{CH_4\ inv.} = \alpha + \underbrace{\sum_{k=1}^{m}[\beta_k y_{it} I(\tau_{k-1} < q_{it} \leq \tau_k)]}_{income\ effect} + \underbrace{Z'_{it}\gamma}_{controls} + \nu_t + \underbrace{u_{it}}_{\mu_i + \epsilon_{it}}$$

- Regime-dependent income-elasticities:

$\rightarrow$ q_{it} threshold variable (exogenous, GDP p.c.; 5y lagged)
$\rightarrow$ τ threshold (endogenously estimated)
$\rightarrow$ FE model estimated by OLS after double-demeaning
$\rightarrow$ IV threshold estimator follows Caner and Hansen (2004)

Summary, threshold model for CH_4:

Results from the treshold model in a nutshell:

- CH_4 increases with income, but elasticity is below 1 % (decoupling) lower than for CO_2
  - → Income-elasticity is much lower than for CO_2 emissions
  - → Income-elasticity increases as countries move from low to higher incomes
  - → The income-elasticity then decreases again at very high income levels
  - → Only the higher threshold remains significant in the IV estimations
- Results for Annex I membership and trade openness point towards CH_4 leakage:
  - → Annex I membership reduced production is outweighed by increases in footprints
  - → Trade increases production of CH_4 inventories

Determinants & income-elasticities very heterogenous across sectors:

→ Results on the sector-level drive economy-wide reults

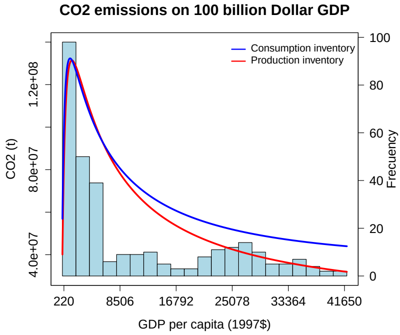
→ Energy, MFC, public admin. (waste management) show the lower-income threshold

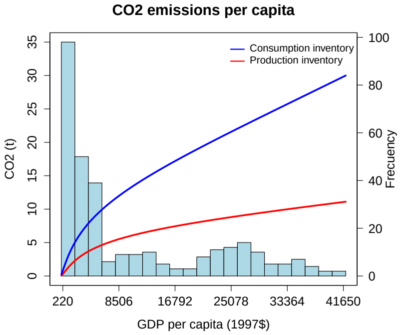
→ Livestock and transport show the threshold at very high income levels

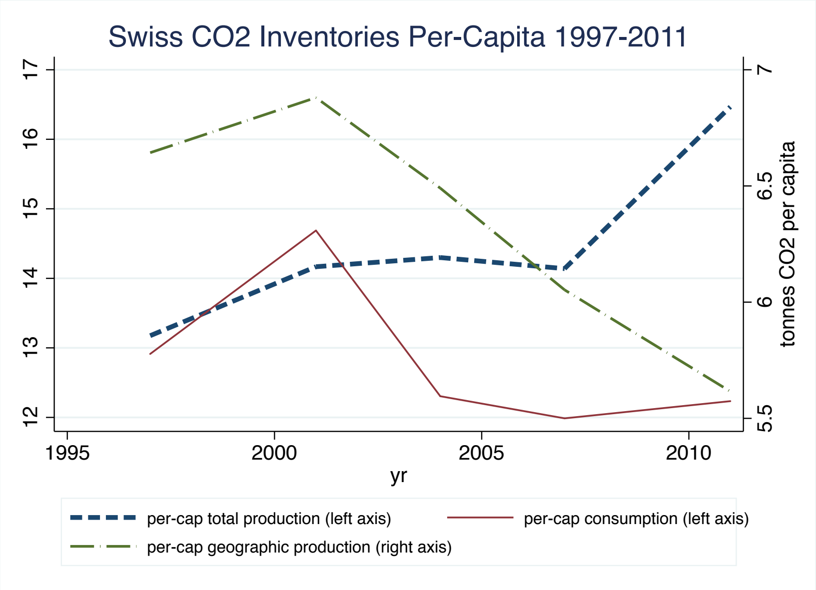
→ In many sectors (40% of emissions) CH_4 is not affected by GDP per capita

→ Sectoral transformation accompanying economic growth seems to drive CH_4 p.c.

Regression in pictures: CO_2 Production, consumption, and income levels: 1997-2011 basis






Swiss CO2 Inventories Per-Capita 1997-2011
17
16
15
14
13
12
7
6.5
6
5.5
tonnes CO2 per capita
1995
2000
2005
2010
yr
per-cap total production (left axis)
per-cap consumption (left axis)
per-cap geographic production (right axis)

Closing rumination, future work

- ⇒ Trade means geographic production targets for carbon can, and apparently actually do lead to leakage.
- ⇒ High income countries may appear clean, but partly by outsourcing carbon
- ⇒ South-South trade at intermediate stages provides a conduit for carbon to enter global value chains that terminate in high income countries.
- ⇒ Consumption patterns show less environmental-efficiency gains from development than production. Methane efficiency is particularly insensitive to per-capita income growth (trash, meat, fracking, ...)
- ⇒ Beyond carbon, even without climate projections, resource use poses unique challenges. MRIO & structural GE modeling may help.
- ⇒ Volume effects with growth swamp efficiency effects. This leads to scary scenarios in the absence of new instruments.
- ⇒ Would resource consumption/content taxes work? R&D subsidies?