MCC

Mercator Research Institute on
Global Commons and Climate Change

How existing technologies can contribute to reducing global CO2-emissions

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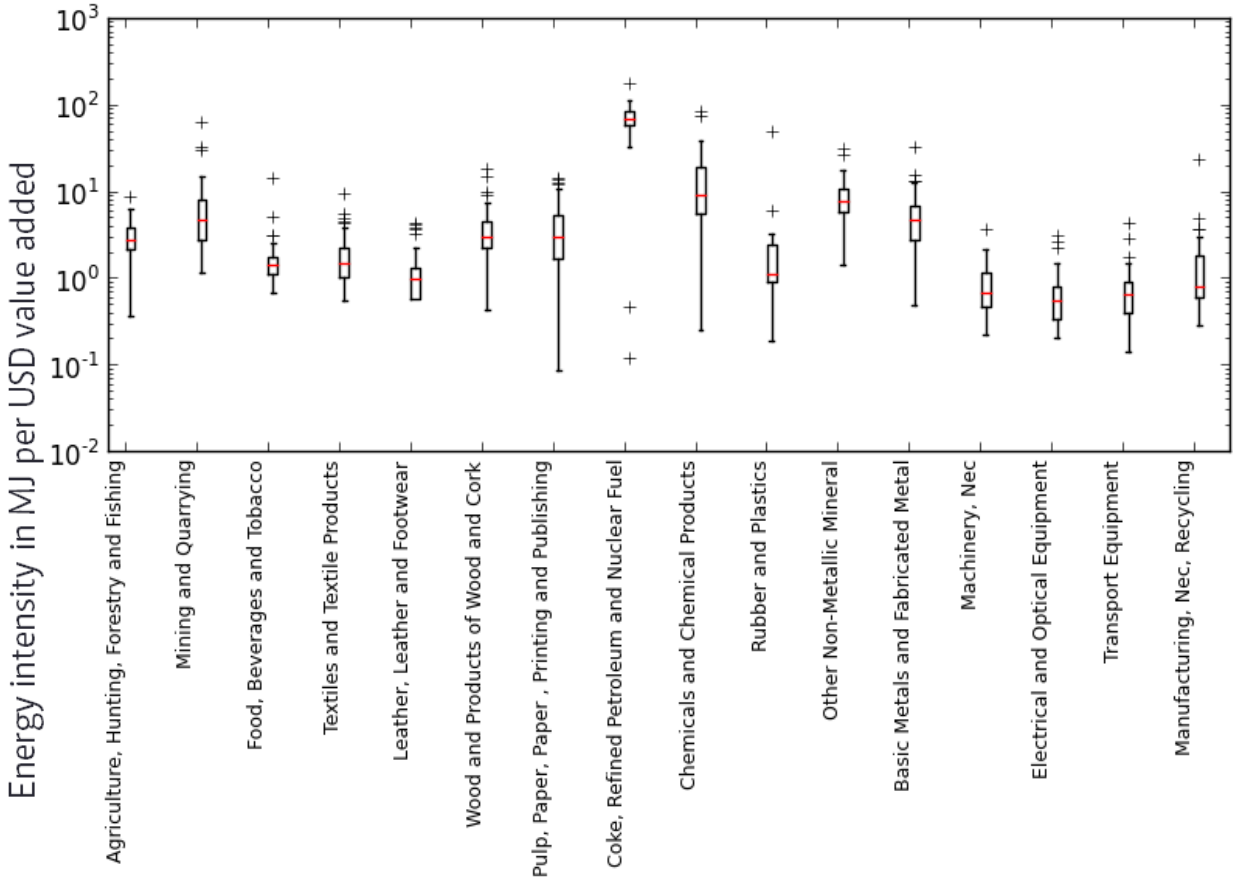
Technology and Environment

Motivation



Visualization of sectoral EIs, WIOD 2009 database

- Differences in sectoral energy intensity (EI) are large (see also Voigt et al. 2014)
- In principle large mitigation potentials exist when efficient technologies were made widely accessible &
- countries without efficient technologies could adapt those
- **How large are those hypothetical emissions reduction potentials?**

Estimating reduction potentials

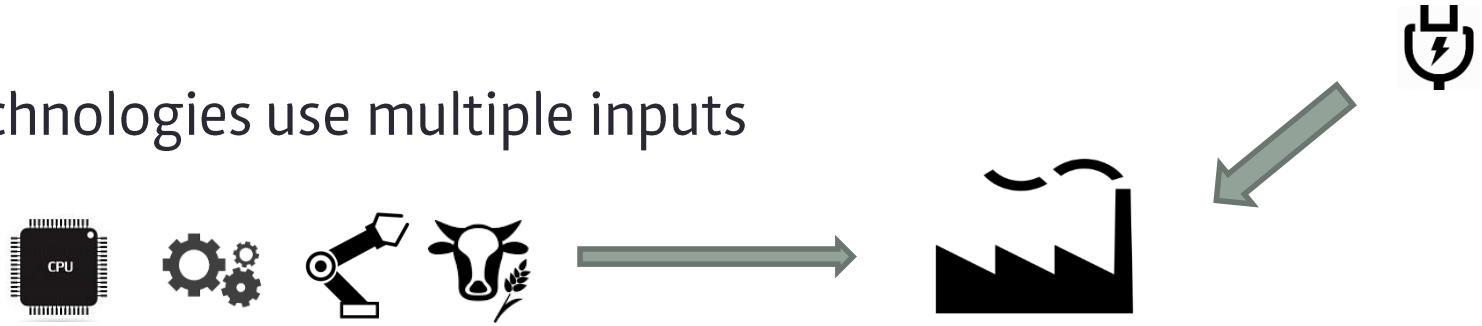
I. Investigation of potentials by direct EI replacement (Saygin et al. 2011) in industrial sectors by best practice technology in use

   reduction potentials of ~27% of global energy usage exist (32.5 exajoules)

II. Kim and Kim (2012): investigation of relative potentials for CO2 emission intensity improvements by consideration of best practice technologies in terms of EI.

A different approach to investigate potentials

- Technologies use multiple inputs



- Low energy intensity might be countervailed by other inputs
- EI and other inputs need to be considered when estimating emissions mitigation potentials
- Consider the network properties of the global economy

Used data: WIOD

- Utilize World Input-Output Database (WIOD) 2009
  - 41 regions (incl. one residual region "RoW") and 35 sectors
  - Assumptions: homogeneity of sectoral outputs, proportionality between monetary and underlying physical flows
  - Each sector considers 35 commodity inputs (from different regions)
  - Data on sectoral energy usage and related emissions
  - Satellite data: labor hours used with corresponding qualification
  - Adaptation of transportation modelling framework by Cristea et al. 2012

Notation, Production functions

- Sectoral output in region r sector s:

$$O_r^s = P(C_1, C_2, \dots, C_{35}, L_1, L_2, L_3, E)$$

- Leontief production function for one good

$$o_r^s = P(c_1, c_2, \dots, c_{35}, l_1, l_2, l_3, e)$$

- Introduce Q
  - extension of O: $\boldsymbol{Q_{il}^j}$
- How much of sector l in region i is produced with the technology of region j
- Q → enables multiple technology use in one sector (up to 41)

Optimization framework

- **Goal:** Exchange technologies in industrial sectors (and restructure production chains) in an optimal manner such that related CO2-emissions are minimized
- Fulfilling final demand, keeping GDP constant
- Due to complexity: linear optimization algorithm
- **Benefits:**
  - Multiple production inputs are accounted for
  - Technologies are exchanged simultaneously and endogenously

Emissions related to objective function

- Sectoral CO2 emissions in WIOD:

$$\boldsymbol{Total\ (CO_2)_r^s = O_r^s \times EI_r^s \times CI_r}$$

- Minimize carbon dioxide emissions linked to production:

$$\mathbf{min}\ \Big(\underbrace{\sum_{r=1}\sum_{j=1}\sum_{s=1} Q_{rs}^{*j} \times EI_j^s \times CI_r}_{\text{Emissions related to production}} + \underbrace{\sum_{r}\sum_{j}\sum_{s} T_{rs}^{j}}_{\text{Transportation}} \Big)$$

- Need of specific side constraints: prevent extremal solutions and consider real world properties

First group of constraints

- Fertile soil and resource abundance are country specific and cannot be exchanged
- Services often serve regional specific needs (military, infrastructure)

→ $\boldsymbol{Q_{il}^{*j} = 0, for\ i \neq j,}$ if i is an agricultural or service sector

Agriculture and extraction sectors cannot expand their production

Service sectors' export value cannot be increased

- Final demand has to be fulfilled

→ $\boldsymbol{\sum_i Y_{i,l}^{j} = \sum_i Y_{i,l}^{*j}, \quad i,j \in R\ and\ l \in S}$

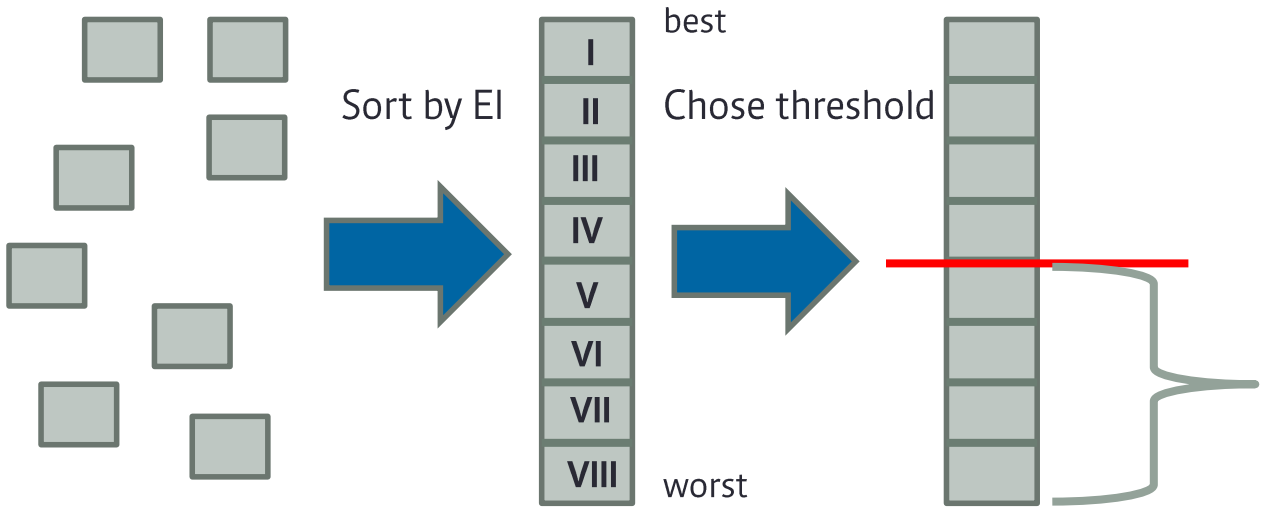
- Regional trade flows and GDP are fixed
  - → $Imp_i^* = Imp_i$
  - → $Exp_i^* = Exp_i$

Further constraints

- No technology exchange for sectors w/o EI or LI
- Labor stocks cannot be overused
- Labor can be shifted intra regionally but not between regions
- Inputs need to be provided
- No overproduction
- Total available energy in each region is limited
- Energy infrastructure cannot be changed, i.e. CI is fixed

Creation of technology pool

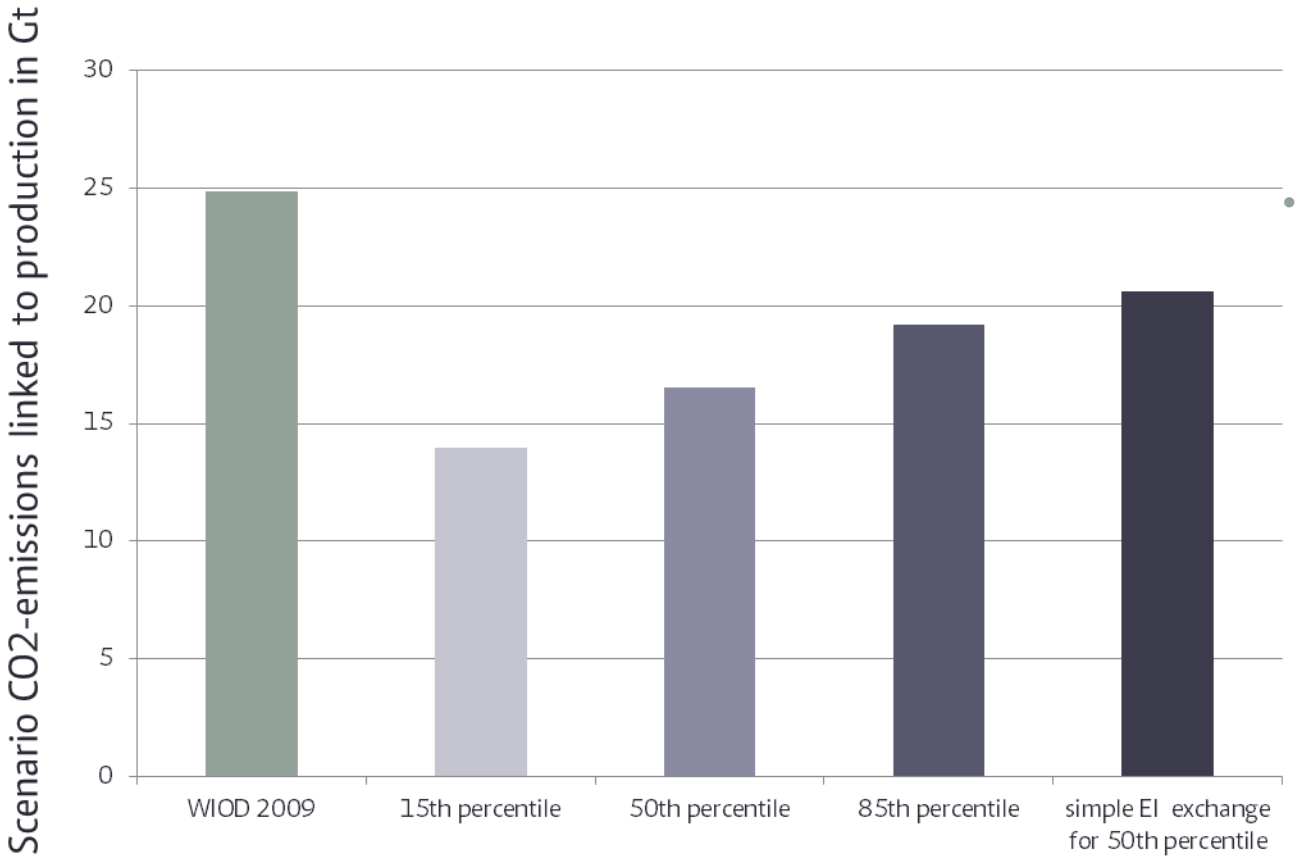
- 41 technologies are available per sector
- Some EI are unrealistic low
- Sort sectoral technologies by energy intensity
- Define scenarios on threshold, which can be adjusted flexibly
- Refer to median technology in this paper as reference
- Common technology pool



-technologies not being part of the pool can still be used locally, but cannot extend production

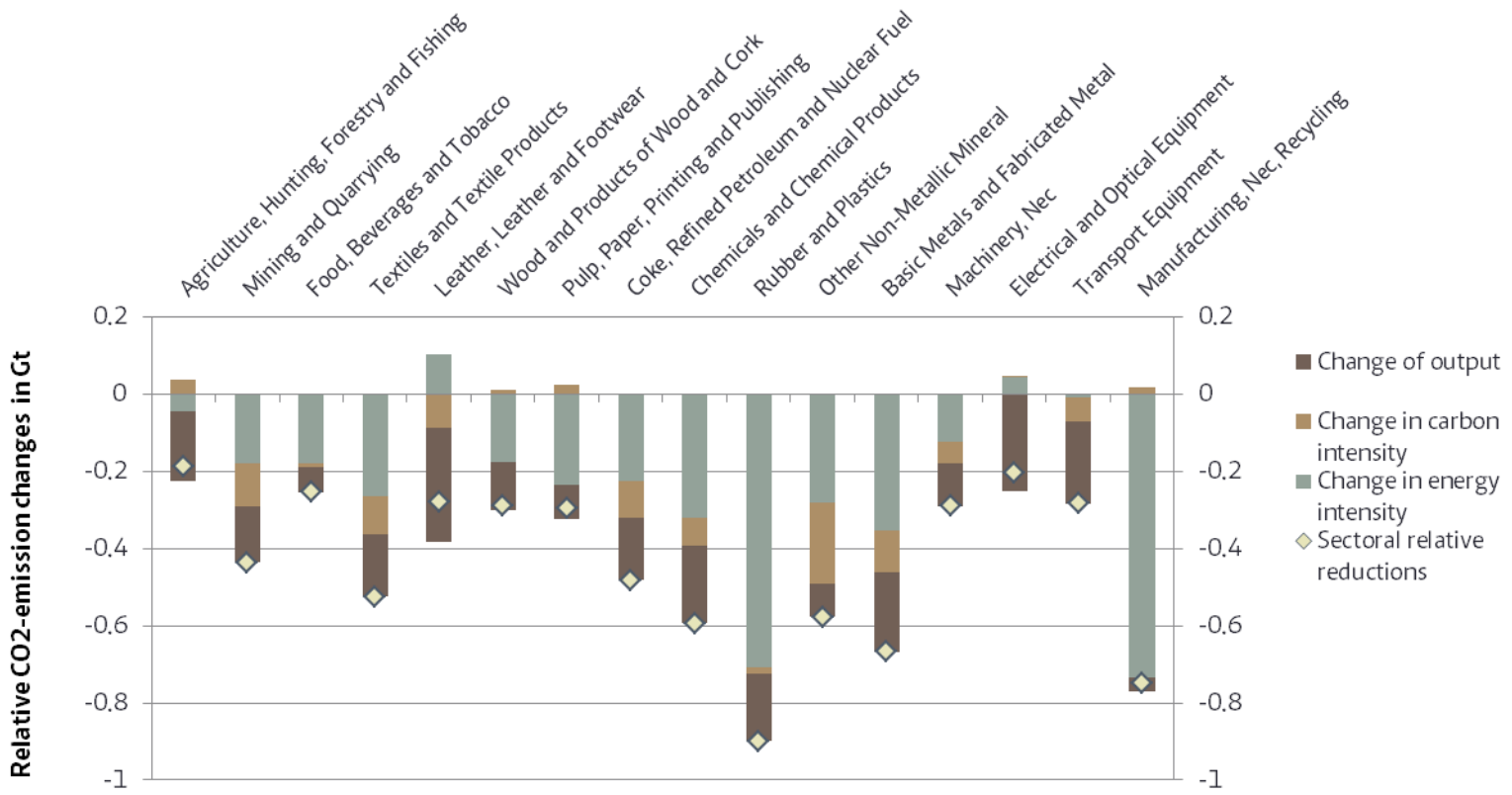
-Pool technologies are available for each region
-can coexist

Results globally



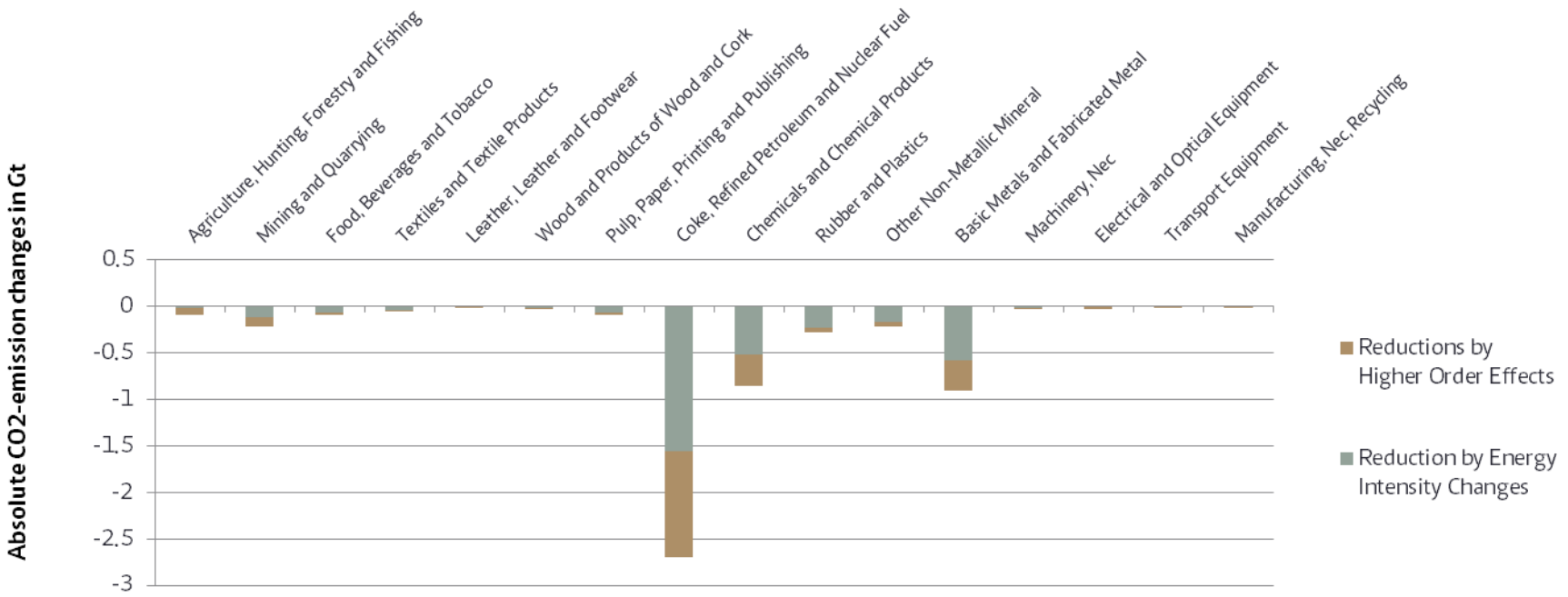
- Consideration of indirect effects leads to substantial improvements
- Large reduction potentials already occur for relatively unambitious scenarios

Decomposition of underlying factors



- Energy intensity is mostly major relevant factor
- Changes due to relative delocalization are of minor relevance
- Not optimal reduction in each single sector, instead optimal global solution

Reductions without delocalization factor



- Absolute reductions w/o delocalization factor are smaller
- Summing over all sectors pure technological reductions yield more than 6.5 Gt of potential reductions, still outperforming "simple EI" exchange (4.3 Gt)

Conclusion

- Indirect effects of technological exchanges (other inputs) are relevant
- Large reduction potentials already exists when less ambitious access to technologies is implemented
- Largest reduction potentials are located around a small specific set of sectors
- Necessity to understand how technology can successfully be transferred

Literature

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