
POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

# Correlations between Human Development and CO2 emissions: projections and implications

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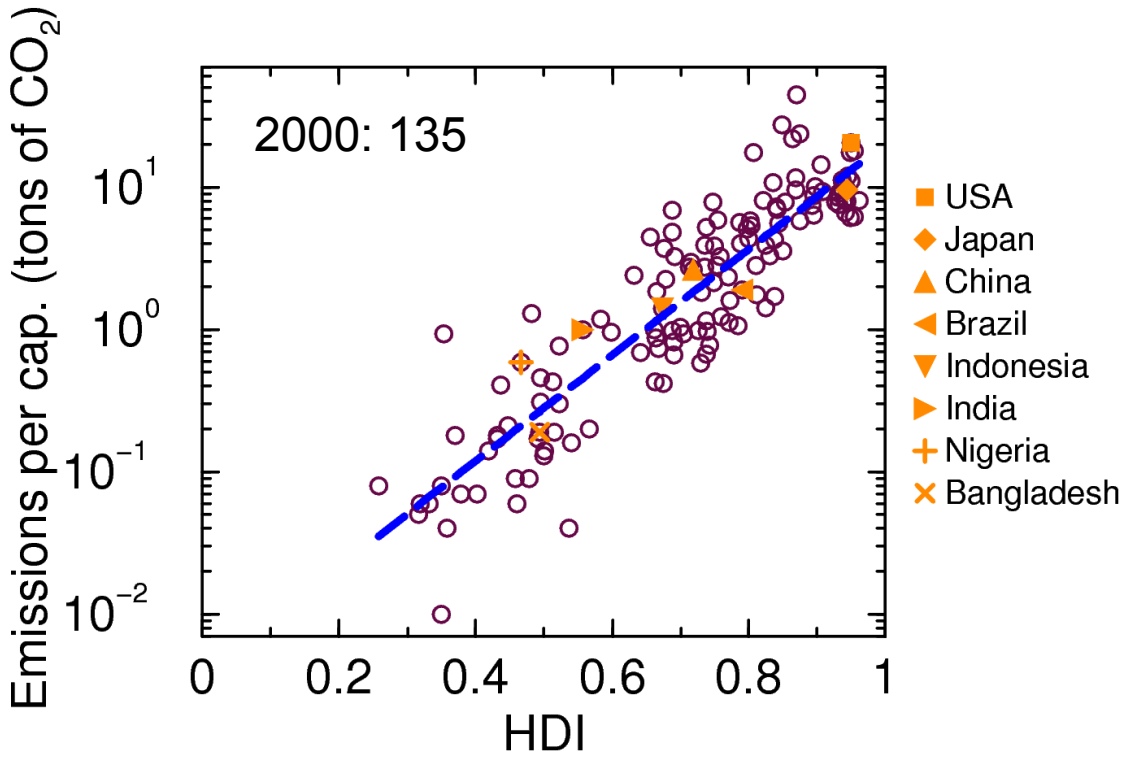
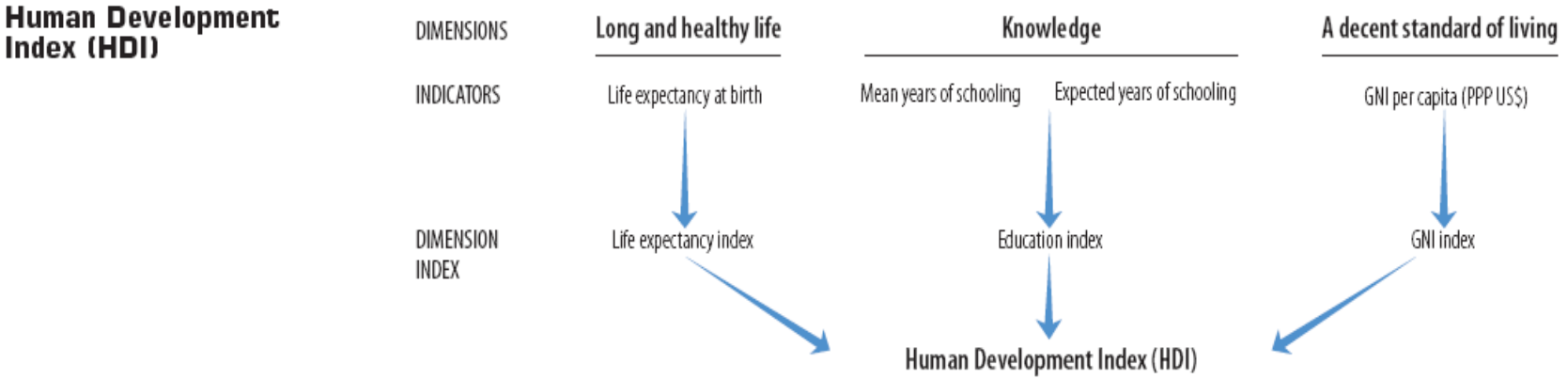
# Correlations between HDI and CO2/cap




- HDI from HDR2009
- correlation coefficient: 0.9
- statistically CO2 emissions per capita increase exponentially with HDI
- how can these correlations be used to project CO2 emissions?

# Human Development Index



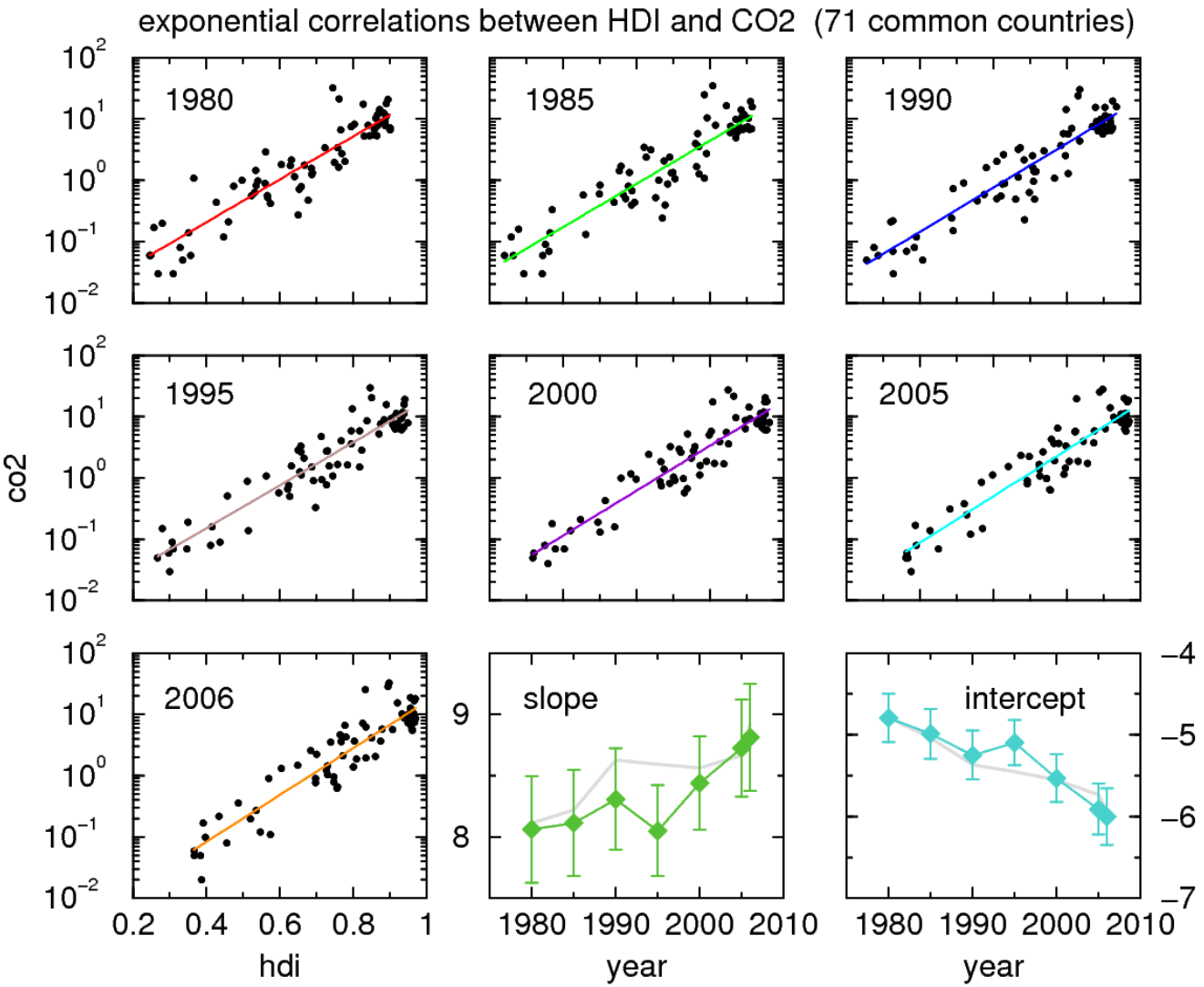

## Goalposts for the Human Development Index in this Report

| Dimension | Observed maximum | Minimum |
|---|---|---|
| Life expectancy | 83.2 (Japan, 2010) | 20.0 |
| Mean years of schooling | 13.2 (United States, 2000) | 0 |
| Expected years of schooling | 20.6 (Australia, 2002) | 0 |
| Combined education index | 0.951 (New Zealand, 2010) | 0 |
| Per capita income (PPP $) | 108,211 (United Arab Emirates, 1980) | 163 (Zimbabwe, 2008) |

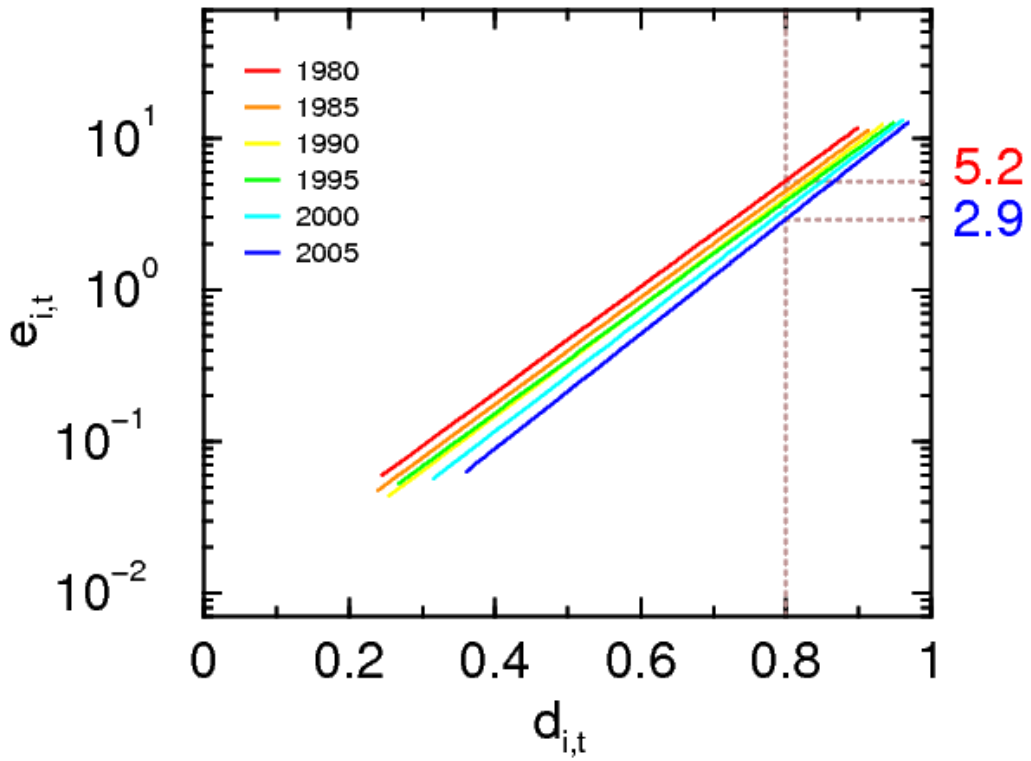
UNDP - 2010

http://hdr.undp.org/en/media/HDR_2010_EN_TechNotes.pdf

# Time dependence



# Time dependence 3




- same HDI (here 0.8)
- but less emissions per capita (in average)

=> increase of efficiency
but small compared to variability!

# Estimating future CO2 emissions

fit to correlated data

$$\hat{e}_{i,t}^{(c)} = e^{h_t d_{i,t} + g_t}$$

parameter

HDI

parameter

CO2 emission
per capita & year

country $i$

year $t$

- data provided my World Resources Institute (WRI)
- CO2 emissions from fossil fuel combustion
- includes CO2 due to cement production
- not included: CO2 due to land use change
- unit: tons of CO2 per year

# Estimating future CO2 emissions

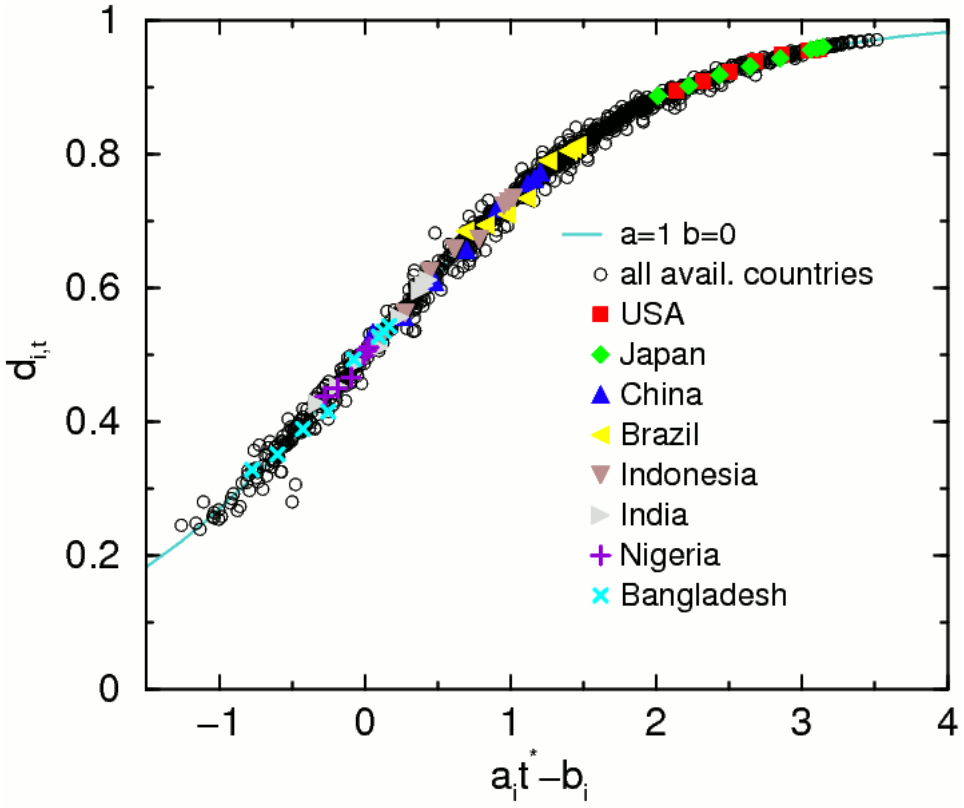
assumptions:

1. HDI in time follows logistic regression

$$\tilde{d}_{i,t} = \frac{1}{1 + \mathrm{e}^{-a_i t + b_i}}$$

- sigmoid function
- originally used to analyze of discrete dependent variables
- but same functional form as Fermi-Dirac distribution
- characteristics (for $a$=1, $b$=0)
- how to fit?

# Logistic regression to HDI

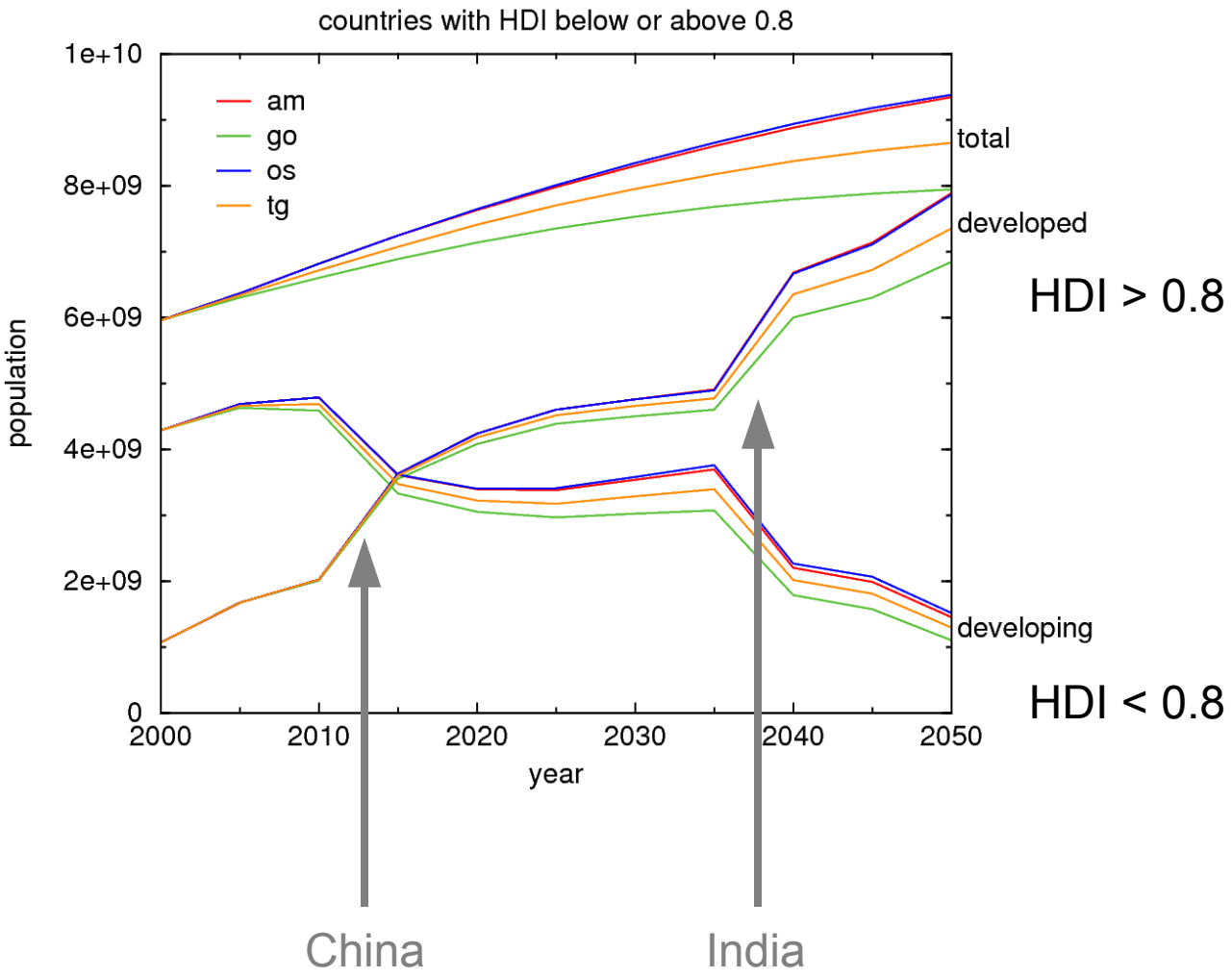



- using the country fitted parameters
  the HDI parameters collapse onto one curve
- no proof of validity of logistic regression

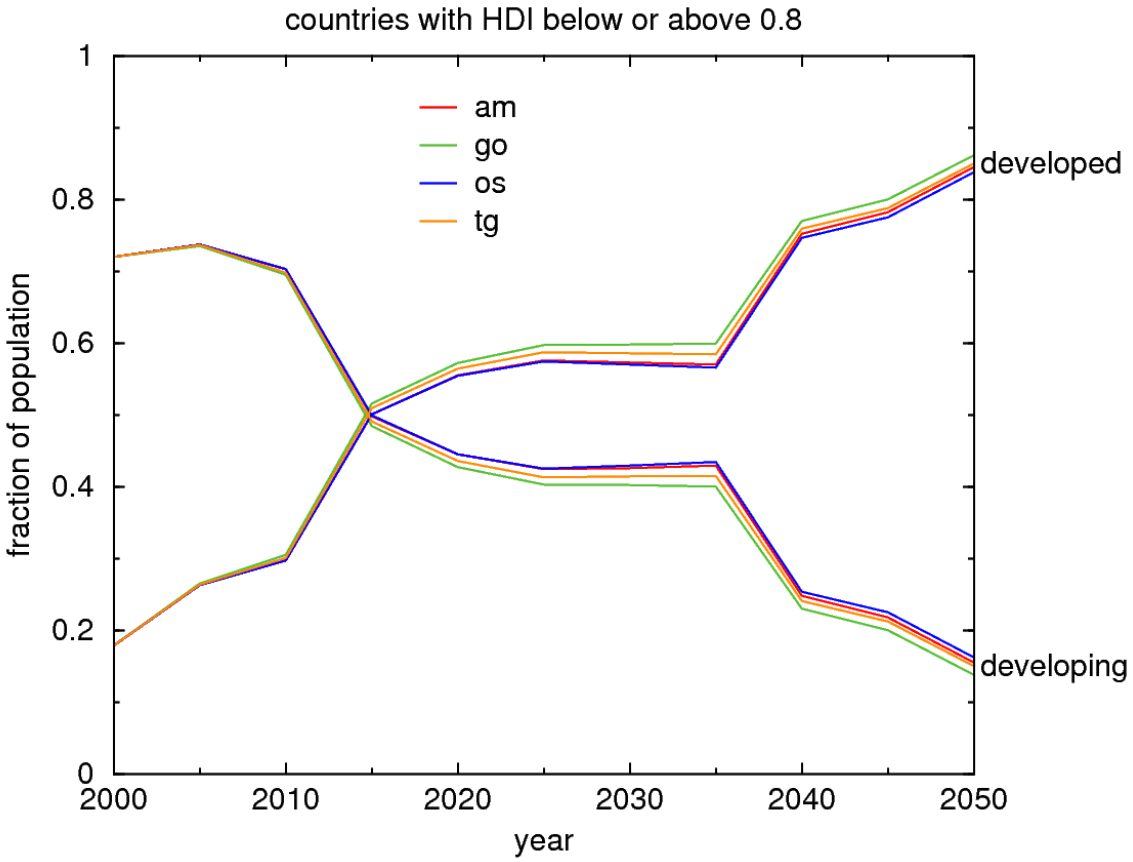
# Implications

| | 2007 2011 | 2012 2016 | 2017 2021 | 2022 2026 | 2027 2031 | 2032 2036 | 2037 2041 | 2042 2046 | 2047 2051 |
|---|---|---|---|---|---|---|---|---|---|
| Armenia | • | | | | | | | | |
| Colombia | • | | | | | | | | |
| Iran | • | | | | | | | | |
| Kazakhstan | • | | | | | | | | |
| Mauritius | • | | | | | | | | |
| Peru | • | | | | | | | | |
| Turkey | • | | | | | | | | |
| Ukraine | • | | | | | | | | |
| Azerbaijan | | • | | | | | | | |
| Belize | | • | | | | | | | |
| China | | • | | | | | | | |
| Dominican.Republic | | • | | | | | | | |
| El.Salvador | | • | | | | | | | |
| Georgia | | • | | | | | | | |
| Jamaica | | • | | | | | | | |
| Maldives | | • | | | | | | | |
| Samoa | | • | | | | | | | |
| Suriname | | • | | | | | | | |
| Thailand | | • | | | | | | | |
| Tonga | | • | | | | | | | |
| Tunisia | | • | | | | | | | |
| Algeria | | | • | | | | | | |
| Bolivia | | | • | | | | | | |
| Fiji | | | • | | | | | | |
| Honduras | | | • | | | | | | |
| Indonesia | | | • | | | | | | |
| Jordan | | | • | | | | | | |
| Sri.Lanka | | | • | | | | | | |
| Sri.Lanka | | | • | | | | | | |
| Syrian.Arab.Republic | | | • | | | | | | |
| Turkmenistan | | | • | | | | | | |
| Viet.Nam | | | • | | | | | | |
| Cape.Verde | | | | • | | | | | |
| Egypt | | | | • | | | | | |
| Equatorial.Guinea | | | | • | | | | | |
| Guatemala | | | | • | | | | | |
| Guyana | | | | • | | | | | |
| Mongolia | | | | • | | | | | |
| Paraguay | | | | • | | | | | |
| Philippines | | | | • | | | | | |
| Kyrgyzstan | | | | | • | | | | |
| Nicaragua | | | | | • | | | | |
| Uzbekistan | | | | | • | | | | |
| Lao.People's.Democratic.Republic | | | | | | • | | | |
| Morocco | | | | | | • | | | |
| Vanuatu | | | | | | • | | | |
| Botswana | | | | | | | • | | |
| India | | | | | | | • | | |
| Nepal | | | | | | | • | | |
| Bangladesh | | | | | | | | • | |
| Sao.Tome.and.Principe | | | | | | | | • | |
| Yemen | | | | | | | | • | |
| Bhutan | | | | | | | | | • |
| Ethiopia | | | | | | | | | • |
| Pakistan | | | | | | | | | • |
| Solomon.Islands | | | | | | | | | • |
| Uganda | | | | | | | | | • |

# Implications



# Implications




- after 2015 half of world population developed
- 85% of world population developed

# Estimating future CO2 emissions

assumptions:

1. HDI in time follows logistic regression

$$\tilde{d}_{i,t} = \frac{1}{1 + \mathrm{e}^{-a_i t + b_i}}$$

2. HDI and logarithm of CO2/cap are linearly correlated

ensemble:

$$\hat{e}^{(\mathrm{c})}_{i,t} = \mathrm{e}^{h_t d_{i,t} + g_t}$$

individual:

$$\tilde{e}^{(\mathrm{c})}_{i,t} = \mathrm{e}^{h_i d_{i,t} + g_i}$$

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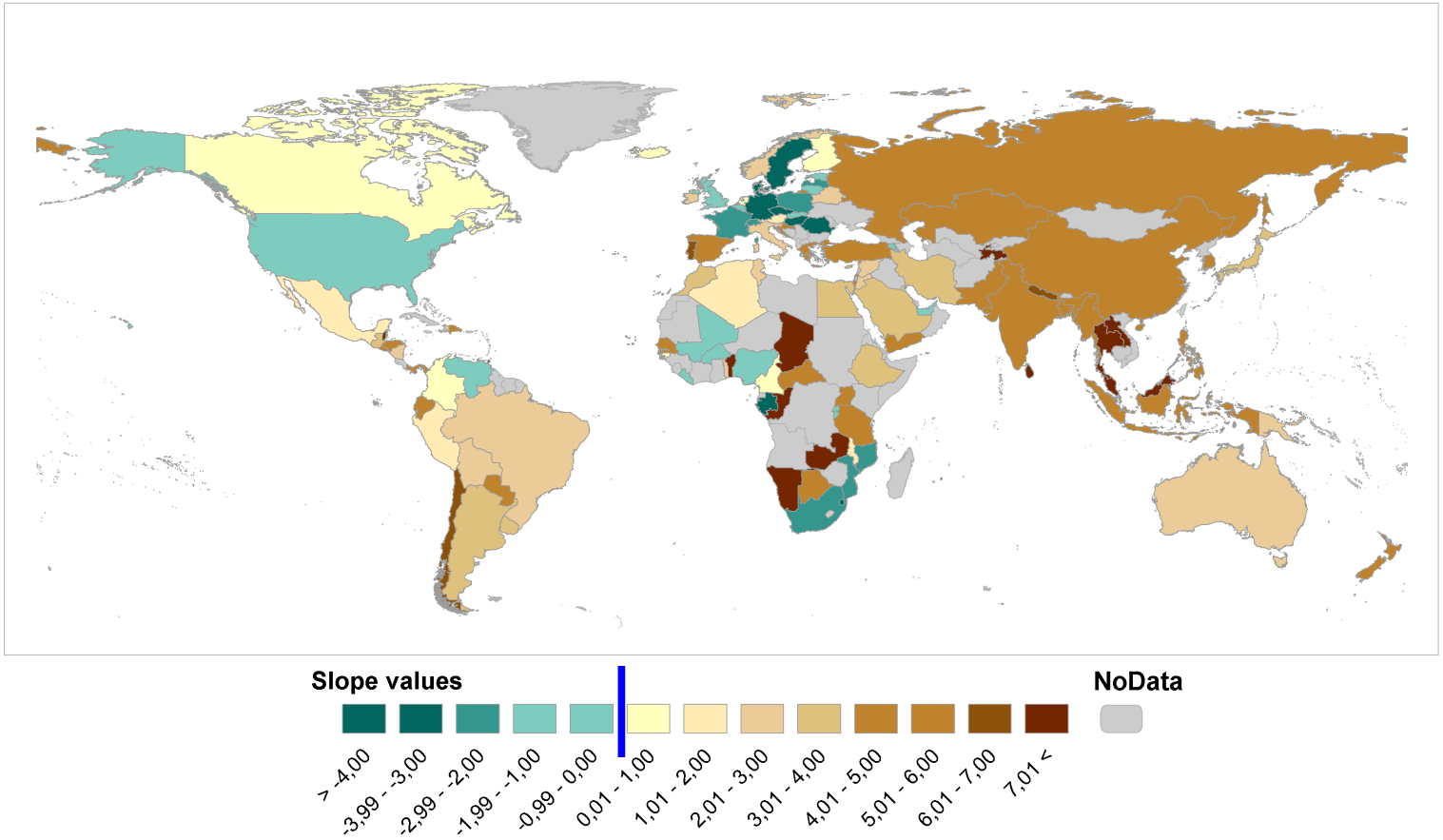
individual:

$$\tilde{e}^{(\mathrm{c})}_{i,t} = \mathrm{e}^{h_i d_{i,t} + g_i}$$

(some countries have $h$<0)

# Individual correlations

Slope of the regression between HDI and CO2 per capita




decreasing per cap emissions with increasing HDI

increasing per cap emissions with increasing HDI

# Estimating future CO2 emissions

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$$\tilde{d}_{i,t} = \frac{1}{1 + \mathrm{e}^{-a_i t + b_i}}$$

2. HDI and logarithm of CO2/cap are linearly correlated

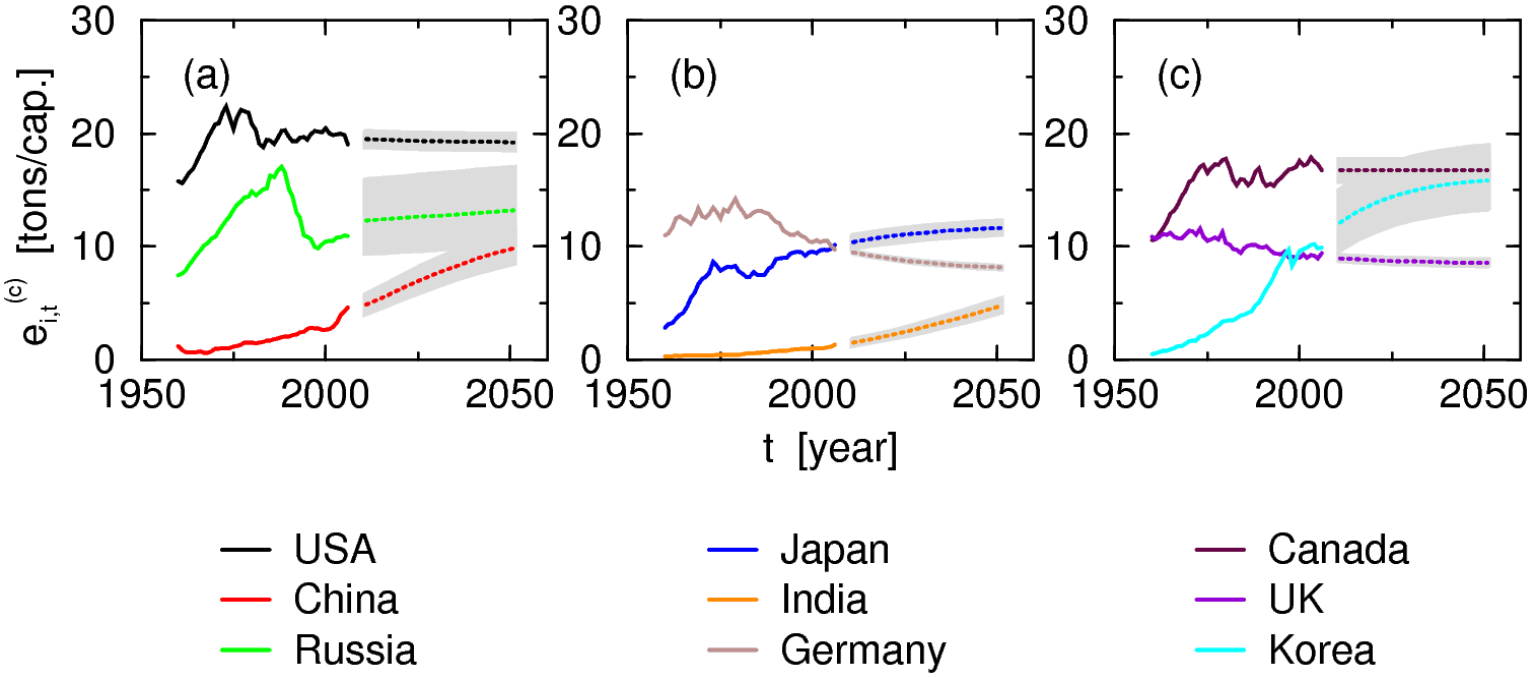
$$\tilde{e}^{(\mathrm{c})}_{i,t} = \mathrm{e}^{h_i d_{i,t} + g_i}$$

3. Changes in both quantities are correlated between the countries

$$c_{i,j}(\Delta d) = \frac{(\delta d_i - \langle \delta d \rangle)(\delta d_j - \langle \delta d \rangle)}{\sigma^2_{\delta d}}$$

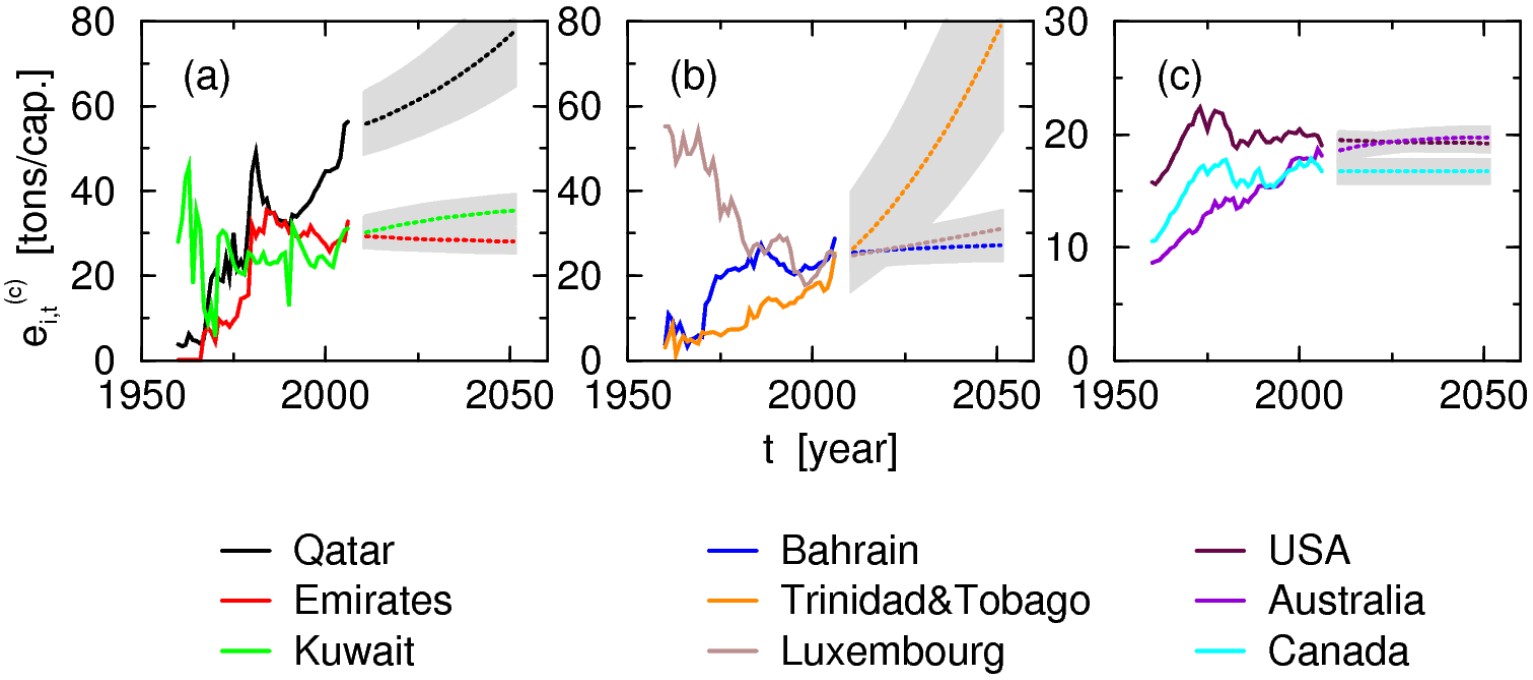
- analogous for emissions
- used for countries with missing data

# Examples 1

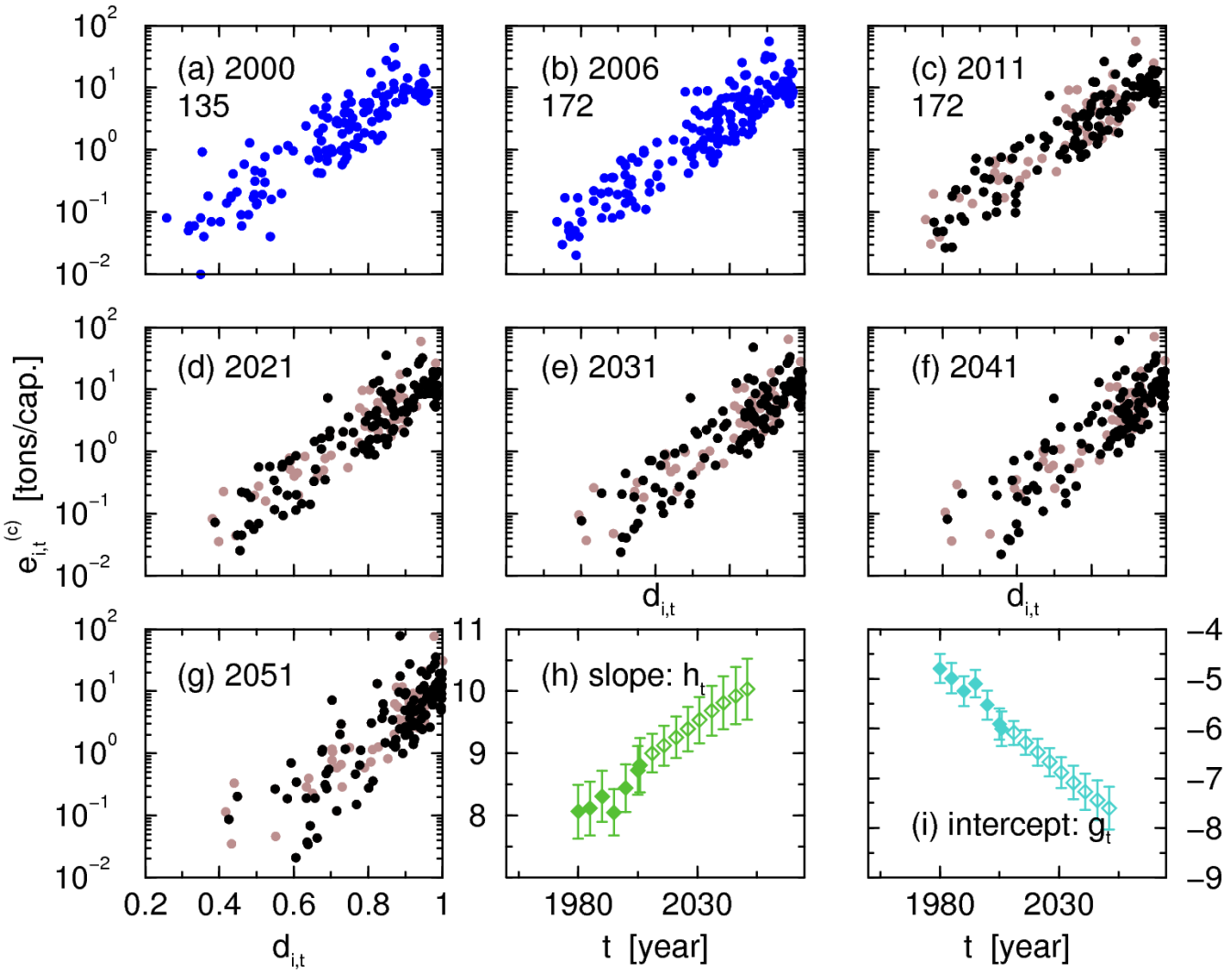



- large uncertainty is due to poor correlations
- high HDI countries comprise small changes
- per capita emissions in China will double by 2050
- per capita emissions in India will triple

# Examples 2


(a)
(b)
(c)
$e_{i,t}^{(c)}$ [tons/cap.]
t [year]
Qatar
Emirates
Kuwait
Bahrain
Trinidad&Tobago
Luxembourg
USA
Australia
Canada

# Projected per capita emissions



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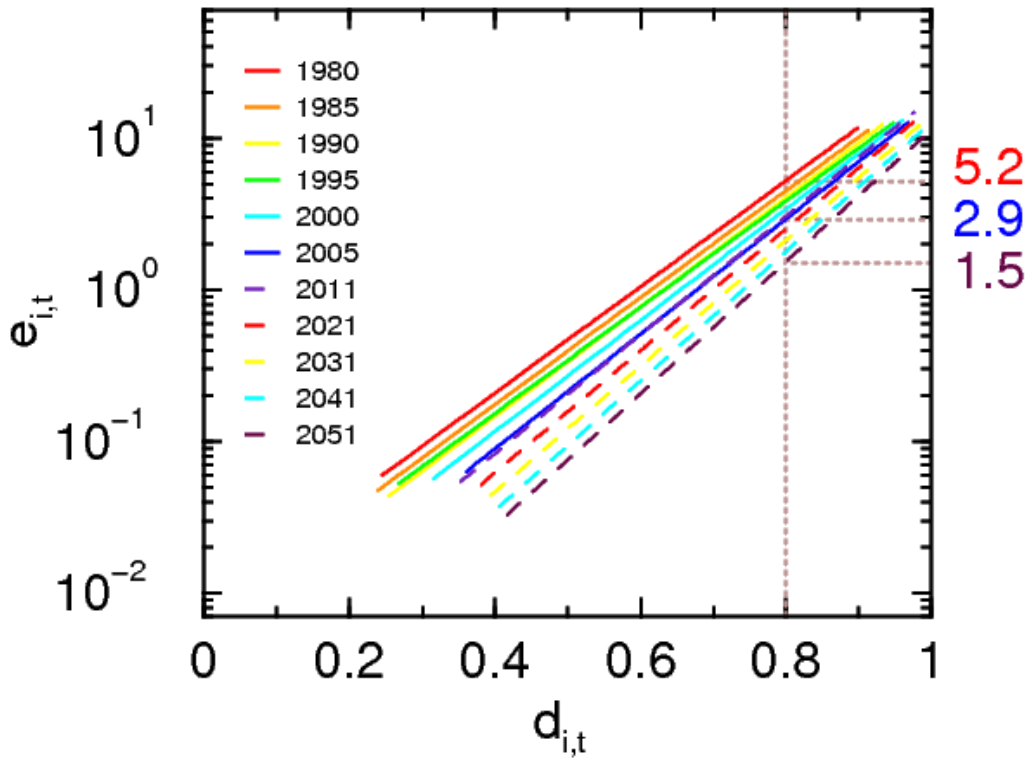


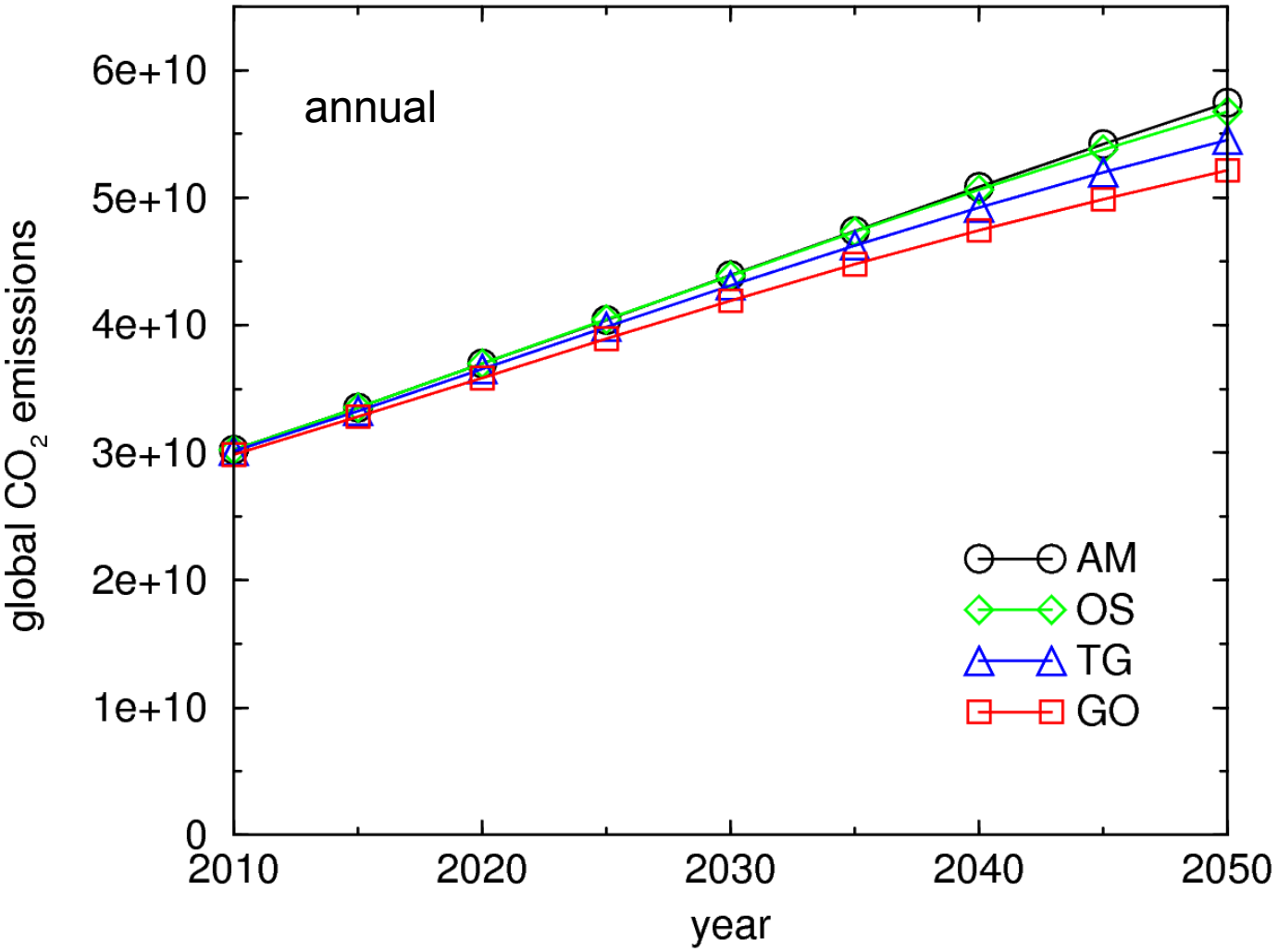

- expected per capita emissions of HDI 0.8 countries in 2050: 1.5t/y
- less than 1/3 of the 1980 value

# Projected cumulative emissions

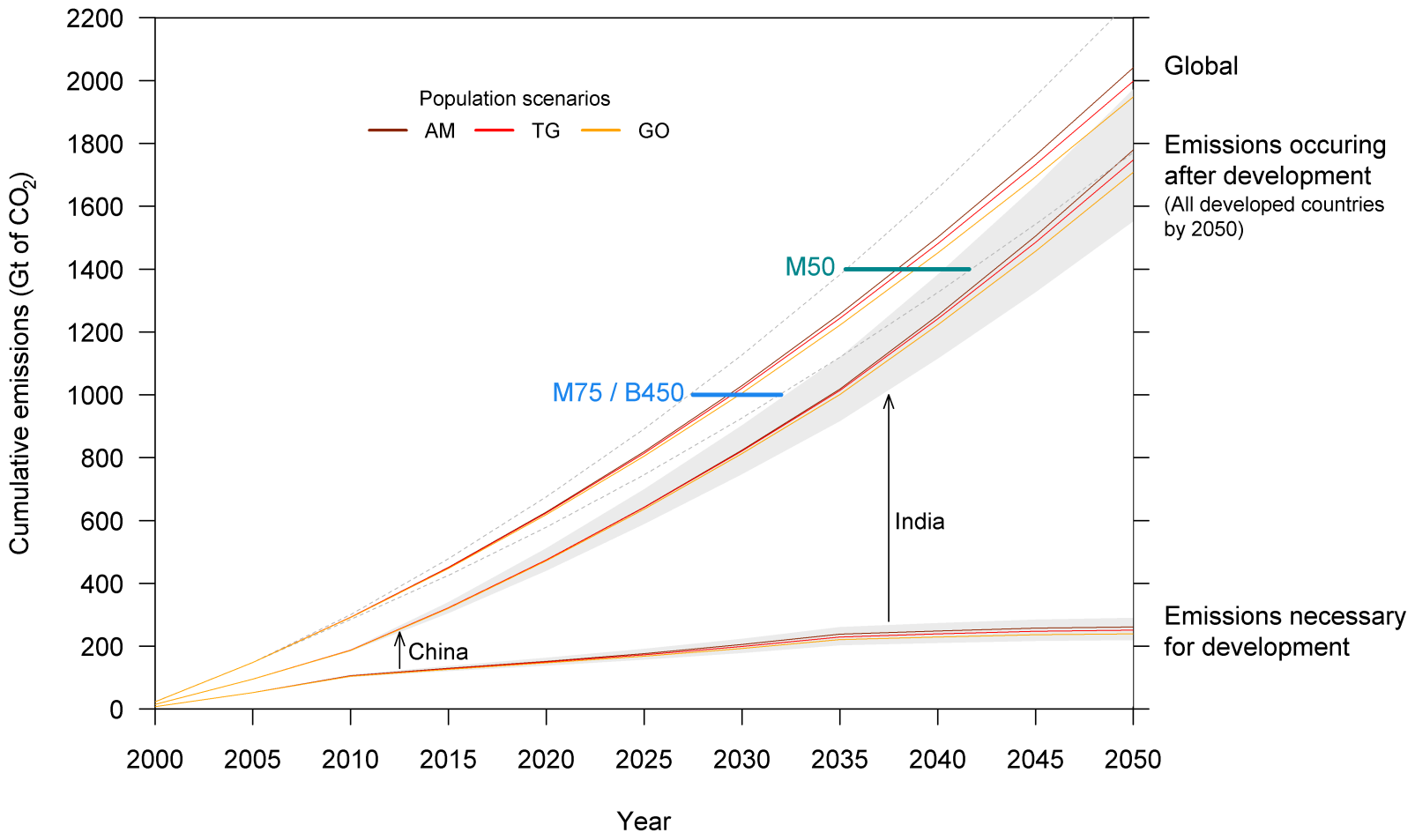
so far: “reasonable” projected per capita CO2 emissions
(majority of countries)

we want:
- total annual emissions for countries
- cumulative emissions

# Projected cumulative emissions



# finally ...


Cumulative emissions (Gt of $CO_2$)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year
Population scenarios
AM
TG
GO
M50
M75 / B450
India
China
Global
Emissions occuring after development
(All developed countries by 2050)
Emissions necessary for development

# Outlook

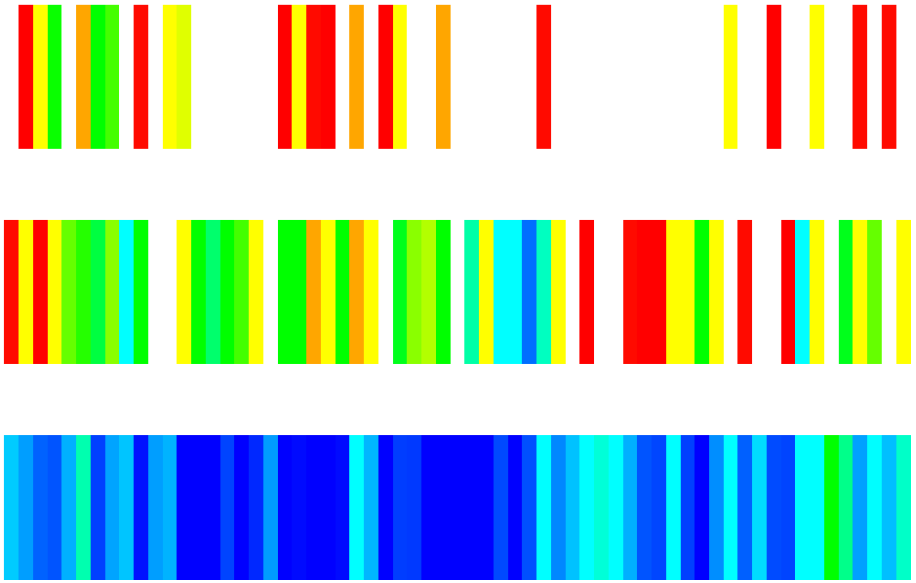
How could an allocation/reduction scheme look like?

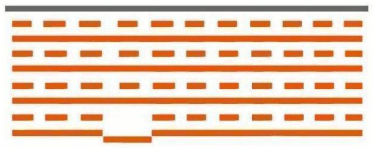
paper:

L. Costa, D. Rybski, J.P. Kropp et al., submitted 2011.

see also: http://arxiv.org/abs/1010.3837

# Thank you for your attention.





http://www.rybski.de/diego/

http://www.pik-potsdam.de/members/rybski/