# $CO_2$ emissions production-based accounting vs consumption

## Insights from the WIOD databases

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# Content



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# GHG Accounting Framework

## Introduction

- Actual GHG accounting system is a production-based accounting:

*"national inventories include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction" IPCC, 2007*

- Thereby, none "official" accounting system considers the consumption side, *i.e.* GHG embodied in goods.

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# GHG Accounting Framework

## An example

**Example**

Country A decides to reduce its power generation capacity without none measure to reduce domestic demand for electricity. So Country A imports electricity from country B to fit its domestic demand which used fossil fuel for its PG.

- With **production-based** accounting, country A becomes virtuous whereas country B degrades its GHG balance.
- But with **consumption-based** GHG accounting, country A will increase its emissions whereas GHG emissions in country B remain the same.

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# GHG Accounting Framework

## A policy issue

- Numerous countries are reluctant to pledge binding commitments

**Example**

In Norway, large part of its GHG emissions comes from **fossil fuels quarrying** that are exported. Thus, to reduce its emissions (counted with production-based), **Norway must reduce its production** whereas it is not the final consumer of the fossils fuels (Peters and Hertwich, 2008).

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# Outline



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# WIOD databases

## *WIOTs* and *Environmental Accounts*

- Use of WIOTs in which "*changes in inventories and valuables*" have been removed and other final consumptions agregated. (1995-2009, 41 countries, 35 economic sectors)
- Use of "*Environmental Accounts*" and especially $CO_2$ emissions distributed between the 36 sectors and 41 countries from 1995 to 2009.

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# MRIO method
## Generalized form

- Use of theorectical framework developed by Peters (2008) for Multi-Regional Input-Output (MRIO) method.
- Starting from WIOTs:

$$x = Ax + f \tag{1}$$

- Where:
  - $x$, is the vector of output,
  - $f$, the final consumptions
  - and $A$, the inter-industrial matrix (measured per unit of output)

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# MRIO method
## Detailed form

- In detail:

$$\begin{pmatrix} x_1 \\ \vdots \\ x_m \\ \vdots \\ x_N \end{pmatrix} = \begin{pmatrix} A_{11} & \cdots & A_{1v} & \cdots & A_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ A_{m1} & \cdots & A_{mv} & \cdots & A_{mN} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ A_{N1} & \cdots & A_{Nv} & \cdots & A_{NN} \end{pmatrix} \begin{pmatrix} x_1 \\ \vdots \\ x_m \\ \vdots \\ x_N \end{pmatrix} + \sum_{m=1}^{N} \begin{pmatrix} f_{1m} \\ \vdots \\ f_{vm} \\ \vdots \\ f_{Nm} \end{pmatrix} \quad (2)$$

- Where:
  - $x_m$, is the vector of output of the country $m$,
  - $f_{v,m}$, a vector of the final demands in country $m$ addressed to country $v$.
  - and $A_{mv}$, the inter-industrial matrix between country $m$ and country $v$.

# MRIO method
## Final good multipliers

- The output can be calculated in terms of final consumption:

$$x = \sum_m (I - A)^{-1} f_m = \sum_m y_m \tag{3}$$

- Thereby, domestic output used for domestic final consumption in country $m$: $y_{m,m} = (1 - A)^{-1} f_{m,m}$
- And, domestic output of country $m$ used for foreign final consumption in country $v$: $y_{m,v} = (1 - A)^{-1} f_{m,v}$

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# MRIO method

## Emissions per origin (1/2)

- Emissions of country $m$ for domestic consumption:
  $E_{m,m} = e_m y_{m,m}$ (with $e_m$: the emissions per unit of output)
- And emissions of country $m$ export in country $v$:
  $E_{m,v} = e_m y_{m,v}$
- Thus, the matrix of embodied emissions can be drawn as:

$$\begin{pmatrix} E_{11} & \cdots & E_{1v} & \cdots & E_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ E_{m1} & \cdots & E_{mv} & \cdots & E_{mN} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ E_{N1} & \cdots & E_{Nv} & \cdots & E_{NN} \end{pmatrix}$$

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# MRIO method
## Emissions per origin (2/2)

- National consumption-based and production-based $CO_2$ emissions are computed as:

$$E^{cons} = E^{d} + E^{imp} + E^{H} \tag{4}$$

$$E^{prod} = E^{d} + E^{exp} + E^{H} \tag{5}$$

- with:
  - $E^{imp} = \sum_{m \neq v} E_{mv}$
  - $E^{exp} = \sum_{v \neq m} E_{mv}$
  - and $E^{H}$: national emissions coming from direct households' consumption.

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# Outline



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# Results
## Aggregated regions

- Aggregated matrices:

1995

| $MtCO_2$ | EU-27 | USA | BRIC | OECD* | RoW | Total |
|---|---|---|---|---|---|---|
| EU-27 | 2 901.9 | 102.5 | 58.1 | 86.1 | 232.1 | 3 380.7 |
| USA | 101.5 | 3 902.0 | 26.3 | 154.7 | 154.4 | 4 339.1 |
| BRIC | 459.1 | 242.1 | 3 841.1 | 258.1 | 231.5 | 5 031.8 |
| OECD* | 87.5 | 186.9 | 36.2 | 1 990.6 | 163.6 | 2 464.8 |
| RoW | 292.9 | 211.2 | 87.2 | 210.4 | 2 931.7 | 3 733.4 |
| Total | 3 842.9 | 4 644.7 | 4 048.9 | 2 700.0 | 3 713.3 | 18 949.8 |

2000

| $MtCO_2$ | EU-27 | USA | BRIC | OECD* | RoW | Total |
|---|---|---|---|---|---|---|
| EU-27 | 2 822.6 | 161.3 | 54.1 | 99.6 | 220.8 | 3 358.4 |
| USA | 112.4 | 4 332.0 | 27.3 | 176.7 | 133.1 | 4 781.6 |
| BRIC | 600.9 | 319.2 | 3 847.8 | 253.5 | 267.1 | 5 288.6 |
| OECD* | 117.4 | 274.1 | 57.5 | 2 173.8 | 173.8 | 2 796.6 |
| RoW | 402.7 | 388.9 | 151.9 | 289.0 | 2 963.2 | 4 195.7 |
| Total | 4 056.1 | 5 475.5 | 4 138.6 | 2 992.6 | 3 758.0 | 20 420.9 |

2005

| $MtCO_2$ | EU-27 | USA | BRIC | OECD* | RoW | Total |
|---|---|---|---|---|---|---|
| EU-27 | 2 892.0 | 146.7 | 77.9 | 102.0 | 284.0 | 3 502.8 |
| USA | 102.1 | 4 257.6 | 35.3 | 142.5 | 125.6 | 4 663.1 |
| BRIC | 675.8 | 548.0 | 5 304.7 | 430.4 | 513.7 | 7 472.5 |
| OECD* | 132.7 | 260.5 | 92.4 | 2 225.4 | 192.0 | 2 903.1 |
| RoW | 557.9 | 456.0 | 306.3 | 365.1 | 3 348.9 | 5 034.3 |
| Total | 4 360.6 | 5 668.8 | 5 816.6 | 3 265.4 | 4 464.3 | 23 575.7 |

2009

| $MtCO_2$ | EU-27 | USA | BRIC | OECD* | RoW | Total |
|---|---|---|---|---|---|---|
| EU-27 | 2 604.1 | 97.3 | 105.5 | 80.1 | 309.8 | 3 196.8 |
| USA | 94.1 | 3 766.6 | 59.8 | 121.0 | 147.2 | 4 188.8 |
| BRIC | 702.1 | 528.1 | 6 824.2 | 458.3 | 858.5 | 9 371.2 |
| OECD* | 121.7 | 190.9 | 144.9 | 2 188.5 | 234.2 | 2 880.2 |
| RoW | 438.2 | 279.0 | 351.3 | 283.3 | 3 905.4 | 5 257.2 |
| Total | 3 960.2 | 4 861.9 | 7 485.7 | 3 131.2 | 5 455.0 | 24 894.1 |

**: Australia, Canada, Japan, South Korea, Mexico and Turkey*

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# Outline



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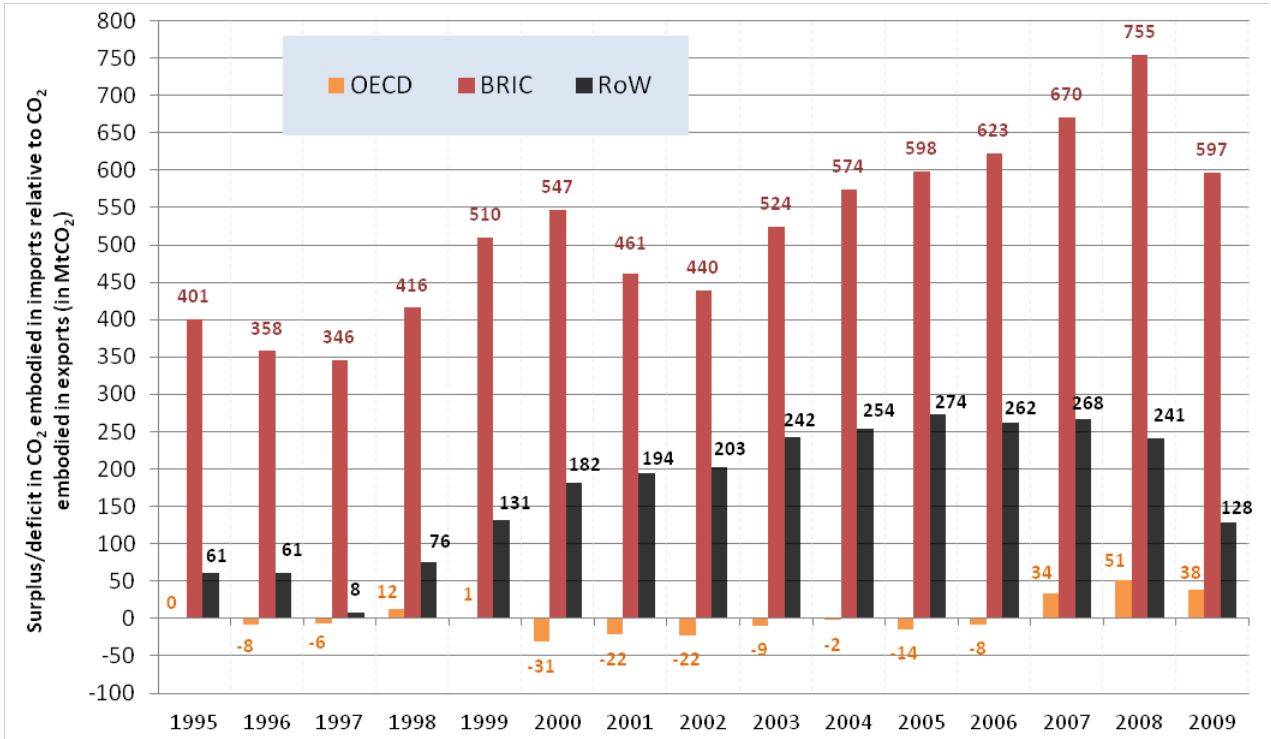
# Results
## EU-27 analysis

- **EU-27** $CO_2$ consumption surplus evolution between 1995 and 2009 with 3 aggregated regions:

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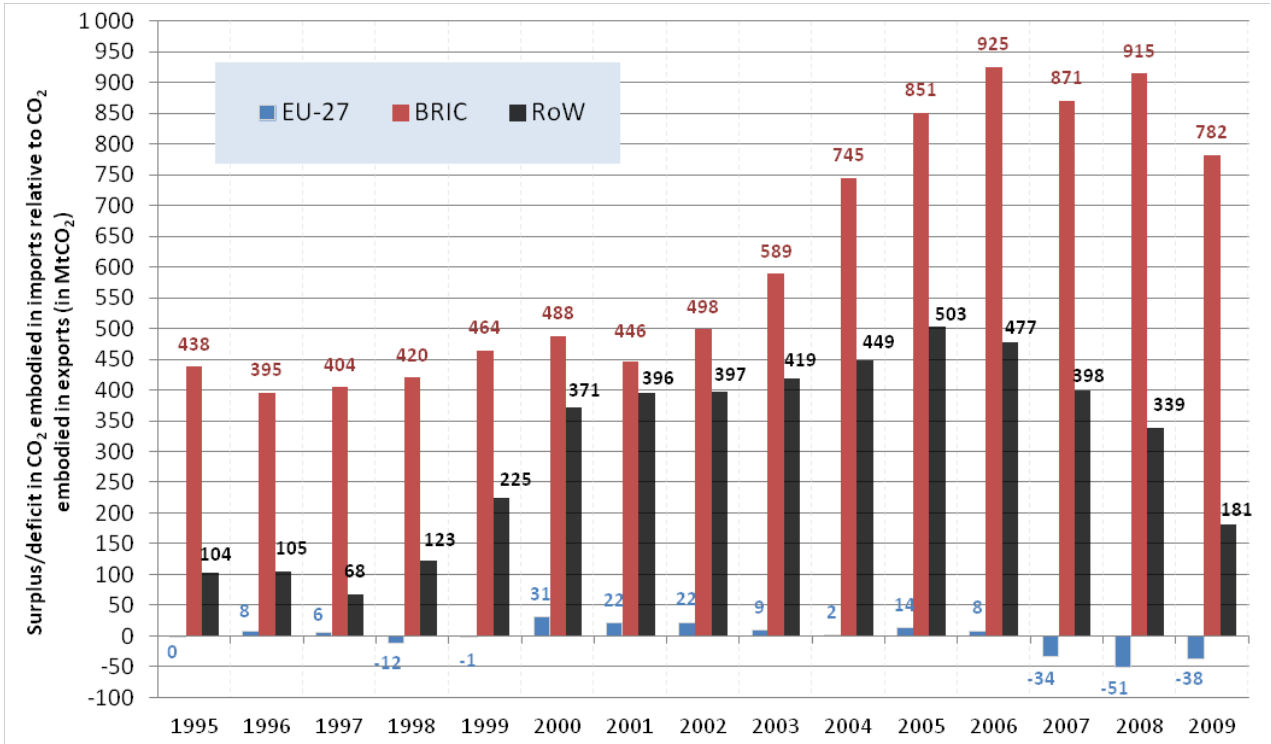
# Results
## OECD analysis

- **OECD** $CO_2$ consumption surplus evolution between 1995 and 2009 with 3 aggregated regions:

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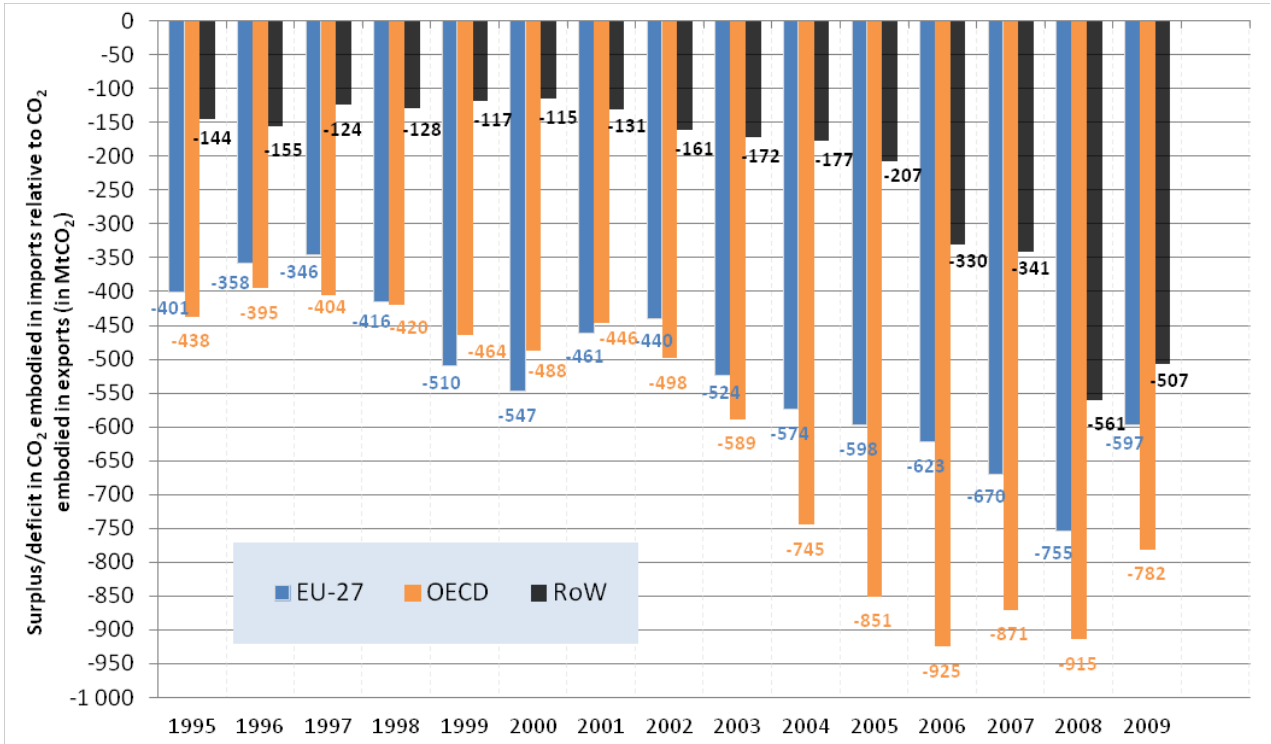
# Results
## BRIC analysis

- **BRIC** $CO_2$ consumption deficit evolution between 1995 and 2009 with 3 aggregated regions:

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# Outline



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# Two groups

- Two groups of countries can be distinguished:
  - "***$CO_2$-consumers***": developed countries, including EU-27 (and especially EU-15) and OECD countries in which $CO_2$ emissions from production are lower than $CO_2$ emissions embodied in goods.
  - And "***$CO_2$-producers***": developing countries (BRIC) and at a lesser extent the Rest of the World in which $CO_2$ emissions embodied in exports are higher than $CO_2$ emissions embodied in imports.

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# $CO_2$ Evolution

- **The gap between $CO_2$ embodied in consumption and $CO_2$ emissions taking place within the territory is increasing** with a strong accelaration between 2002 and 2005
  - in 1995, EU-27 surplus in $CO_2$ consumption was about +460 $MtCO_2$ (*i.e.* +11% compared to production-based $CO_2$) and it was about +1 050 $MtCO_2$ in 2008 (*i.e.* +19%)
  - in 1995, BRIC deficit was about -980 $MtCO_2$ (*i.e.* -17% compared to production-based $CO_2$) and it was about -1 900 $MtCO_2$ in 2008 (*i.e.* -18%)

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# Policy implication

## Examples

Two questions:

- How to carry out international negotiation on climate change without considering those aspects?
- What extent do economic instruments used by European Union mitigation policy (such as EU-ETS market) are relevant in tackling its objective: to fight global warming?

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# Future research

- Realised the same work for GHG emissions and for others environmental issues
- More detailed analysis by country
- Including sectors in the analysis
- Trying to show the existence or not of carbon leakage in EU
- Develop tools (applied economic models) able to consider both GHG accounting
- And use those tools to comparing economic instrument efficiency
- ...

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# Acknowledgments

**Thanks for your attention**

# Acknowledgments

**Thanks to WIOD consortium**

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# Acknowledments

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