Structural Decomposition Analysis of Pollution Terms of Trade

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Outline

• Introduction
• Methodology
• Results
• Conclusions
Introduction

Pollution Terms of Trade = Pollution Embodied in Exports / Pollution Embodied in Imports (Antweiler, 1996)

Factors:
- Emission Intensity: per output emission
- Production Technology: A matrix
- Final Demand: F matrix

Note: we also distinguish between factors related to the domestic country and factors related to foreign countries.
Motivation

Changes in Pollution embodied in trade
All over the world:
\[ \Delta \text{PEE} = \Delta \text{PEM} \]

But in a specific country:
how \( \Delta \text{PEE} \) & \( \Delta \text{PEM} \) and why (Many previous studies)

We found in 32 countries both PEE and PEM increased (1995-2009)
Relative change:
\[ \frac{\text{PEE}_t}{\text{PEE}_{t-1}} \text{?} \frac{\text{PEM}_t}{\text{PEM}_{t-1}} \]
→ change in PTT
\[ \frac{\text{PTT}_t}{\text{PTT}_{t-1}} \text{?} \frac{\text{PEE}_{t-1}}{\text{PEM}_{t-1}} / \frac{\text{PEE}_t}{\text{PEM}_t} \]
→ which factor make changes in PEE larger (smaller) than changes in PEM?
Motivation

International trade changes $\rightarrow$ change in Pollution embodied in trade

All over the world:

$$\frac{\Delta \text{PEE}}{} = \frac{\Delta \text{PEM}}{}$$

But in a specific country:

how $\Delta \text{PEE}$ & $\Delta \text{PEM}$ and why (Many previous studies…)

We found in 8 countries PEE ↓ and PEM ↑ (1995-2009)

Relative change:

$$\frac{\text{PEEt}}{} / \frac{\text{PEE}_{t-1}}{} / \frac{\text{PEMt}}{} / \frac{\text{PEM}_{t-1}}{} < 1$$

$\Rightarrow$ which factor leads to $\frac{\text{PTTt}}{} / \frac{\text{PTT}_{t-1}}{} < 1$ ?
Motivation

For example: from 1995 to 2009

Absolute changes (in ton):

<table>
<thead>
<tr>
<th></th>
<th>$\Delta$PEE</th>
<th>$\Delta$PEM</th>
<th>diff</th>
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</thead>
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<tr>
<td>China</td>
<td>+1,510,720</td>
<td>+648,606</td>
<td>862,114</td>
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<tr>
<td>Greece</td>
<td>+25,906</td>
<td>+29,527</td>
<td>-3,621</td>
</tr>
</tbody>
</table>
Motivation

For example:

<table>
<thead>
<tr>
<th></th>
<th>$\triangle$PEE</th>
<th>$\triangle$PEM</th>
<th>diff</th>
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<tr>
<td>China</td>
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## Motivation

For example:

### Absolute changes:

<table>
<thead>
<tr>
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<th>diff</th>
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<td>-3,621</td>
<td>$\rightarrow$ larger in PEM</td>
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### Relative changes:

<table>
<thead>
<tr>
<th></th>
<th>PEE$<em>{09}$/PEE$</em>{95}$</th>
<th>PEM$<em>{09}$/PEM$</em>{95}$</th>
<th>PTT$<em>{09}$/PTT$</em>{95}$</th>
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</thead>
<tbody>
<tr>
<td>China</td>
<td>3.52</td>
<td>7.03</td>
<td>0.5</td>
<td>$\rightarrow$ larger in PEM</td>
</tr>
<tr>
<td>Greece</td>
<td>3.23</td>
<td>2.15</td>
<td>1.5</td>
<td>$\rightarrow$ larger in PEE</td>
</tr>
</tbody>
</table>
Central question in this paper:

- How changes in these factors affect Pollution Terms of Trade
- To what extent do factors’ effects differ between Pollution Embodied in Exports and Pollution Embodied in Imports

Note:
Relative Effects & Absolute Effects
Answers of both question could give us information on emissions embodied in the international trade.
Data

Analytical WIOTs in current prices (1995-2009)
Analytical WIOTs in previous year’s prices (1996-2009)

35 sectors
40 countries + Rest of the World (Analytical WIOTs)
Methodology

Three Factors:

- emission intensity $W$ : total CO$_2$/total output for each sector
- production technology $A$
- final demand $F$

change from 1995 to 2009 affect PEE, PEM, PTT
Methodology

Three Factors:

- Emission intensity $W$ : total CO2/total output
- Production technology $A$:
  - $H$ technology

\[
H^r = \sum_{s=1}^{N} A^{sr}
\]

\[
H^1 = A^{11} + A^{21} + A^{31}
\]
Methodology

Three Factors:

emission intensity $W$ : total CO$_2$/total output

production technology $A$:

$\rightarrow$ H technology

$H^r = \sum_{s=1}^{N} A^{sr}$

$\rightarrow$ T trade

$t_{ij}^{sr} = a_{ij}^{sr} / h_{ij}^r$

$H^1 = A^{11} + A^{21} + A^{31}$

$T^{11} = A^{11} / H^1$
Methodology

Three Factors:

- Emission intensity $W$: total CO$_2$/total output
- Production technology $A$: $H \text{ technology}$
- Trade $T$: $t_{ij}^{sr} = a_{ij}^{sr} / h_{ij}^{r}$

Mathematical expressions:

$$H^r = \sum_{s=1}^{N} A_{sr} \Rightarrow H^r \text{ and } H^{-r}$$
Methodology

Three Factors:

emission intensity $W$ : total CO$_2$/total output

production technology $A$:

$\rightarrow$ H technology

$H^r = \sum_{s=1}^{N} A_{sr}^r \rightarrow H^r$ and $H^r$

$\rightarrow$ T trade

$t_{ij}^{sr} = a_{ij}^{sr} / h_{ij}^{r} \rightarrow T^r$ and $T^r$
Methodology

Three Factors:

- Emission intensity $W$: total CO$_2$/total output
- Production technology $A$: $\rightarrow$ $H$ technology $\rightarrow$ $H^r$ and $H^{-r}$
- Trade $T$: $\rightarrow$ $T^r$ and $T^{-r}$
- Final demand $F$: $\rightarrow$ q level

$q^r = \sum_{s=1}^{N} f^{sr}$
Methodology

Three Factors:

- Emission intensity $W$: total CO$_2$/total output
- Production technology $A$:
  - $H$ technology
  - $H^r$ and $H^{-r}$
- Trade $T$:
  - $T^r$ and $T^{-r}$
- Final demand $F$:
  - $q$ level
  - $d$ trade

Mathematical expressions:

$$q^r = \sum_{s=1}^{N} f^{sr}$$

$$d_{j}^{sr} = f_{j}^{sr} / q_{j}^{r}$$

$$q^1 = f^{11} + f^{21} + f^{31}$$

$$d^{11} = f^{11} / q^1$$
Methodology

Three Factors:

emission intensity $W$ : total CO$_2$/total output
production technology $A$:
  $\rightarrow$ H technology
  $\rightarrow$ $H^r$ and $H^{-r}$

trade $T$:
  $\rightarrow$ $T^r$ and $T^{-r}$

final demand $F$:
  $\rightarrow$ q level
  $\rightarrow$ $q^r$ and $q^{-r}$
  $\rightarrow$ d trade
Methodology

Three Factors:

- **emission intensity** $W$ : total CO2/total output
- **production technology** $A$: $\rightarrow H$ technology, $\rightarrow H^r$ and $H^{-r}$
- **trade** $T$: $\rightarrow T^r$ and $T^{-r}$
- **final demand** $F$: $\rightarrow q$ level, $\rightarrow q^r$ and $q^{-r}$
- **trade** $d$: $\rightarrow d^r$ and $d^{-r}$

\[
\begin{align*}
\sum_{s=1}^{N} f_{jsr}^{sr} & = \frac{q_{jr}^{sr}}{q_{jr}^{r}} \rightarrow d_{jr}^{sr} & \rightarrow d^r \text{ and } d^{-r}
\end{align*}
\]
Methodology

Three Factors:

- emission intensity $W$ : total CO$_2$/total output
- production technology $A$: $\rightarrow H \text{ technology} \rightarrow H^r$ and $H^{-r}$
  $\rightarrow T \text{ trade} \rightarrow T^r$ and $T^{-r}$
- final demand $F$: $\rightarrow q \text{ level} \rightarrow q^r$ and $q^{-r}$
  $\rightarrow d \text{ trade} \rightarrow d^r$ and $d^{-r}$

PEE, PEM, and PTT: each year changes without price effects
Methodology

Each year changes (in ratios $V_t/V_{t-1}$) without price effects:

...

Obtain the two polar decomposition results, then take average.

$$\frac{V_t}{V_{t-1}} = \sqrt{\frac{V_t}{V_{t-1 \text{ polar} 1}} \times \frac{V_t}{V_{t-1 \text{ polar} 2}}}$$
Methodology

Each year changes (in ratios $V_t/V_{t-1}$) without price effects:

...

The total changes $= (V_{1996}/V_{1995}) \times (V_{1997}/V_{1996}) \times \ldots \times (V_{2009}/V_{2008})$
$= V_{2009}/V_{1995}$
Figure 1: Ratios of PEE (PEM) in 2009 to PEE (PEM) in 1995
Figure 1: Ratios of PEE (PEM) in 2009 to PEE (PEM) in 1995
Results, total changes

Figure 2: Ratios of PTT in 2009 to PTT in 1995
Results, total changes

Figure 2: Ratios of PTT in 2009 to PTT in 1995

<table>
<thead>
<tr>
<th></th>
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<td>32+ 8-</td>
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Legend: R_9509
Results, emission intensity

Figure 3: Emission Intensity Effects on PEE and PEM
significantly negatively correlated, with the correlation coefficient -0.35 and p-value 0.025.
Results, emission intensity

Figure 4: Emission Intensity Effects on PTT
Results, emission intensity

Figure 4: Emission Intensity Effects on PTT
Results, production technology

Production technology → PEM (all) & PEE (in 26 countries) increase

Fragmentation in intermediate products increase PEM:

• imported intermediates/total inputs in each sector each country
• compare year 1995 and 2009
• the average ratio in 1995 is 0.2245
• the average ratio in 2009 is 0.2443 → increased 0.02 or 9%
• weighted average ratio in 1995 is 0.1294
• weighted average ratio in 2009 is 0.1598 → increased 0.03 or 19%
Final demand $\rightarrow$ PEE & PEM increase

Fragmentation in final demand increase PEE and PEM:

- imported final demand/total final
- compare year 1995 and 2009
- the average ratio in 1995 is 0.1284
- the average ratio in 2009 is 0.1387 $\rightarrow$ increased 0.01 or 8%
- weighted average ratio in 1995 is 0.0736
- weighted average ratio in 2009 is 0.0870 $\rightarrow$ increased 0.013 or 18%
Results, PEE and PEM

- Improvement in emission intensity → PEE and PEM decrease
- Final demand → PEE and PEM increase
  - final demand effect partly offset by efficiency effect
Results, PEE and PEM

- Improvement in emission intensity → PEE and PEM decrease
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- Production technology → PEM increase, PEE
Results, PEE and PEM

Improvement in emission intensity → PEE and PEM decrease
Final demand → PEE and PEM increase
  final demand effect partly offset by efficiency effect
Production technology → PEM increase, PEE

Large positive effects from
  overall level of final demand q → q^r on PEM and q^{-r} on PEE
Results, PEE and PEM

Improvement in emission intensity $\rightarrow$ PEE and PEM decrease
Final demand $\rightarrow$ PEE and PEM increase
  final demand effect partly offset by efficiency effect
Production technology $\rightarrow$ PEM increase, PEE

Large positive effects from
  overall level of final demand $q \rightarrow q^r$ on PEM and $q^{-r}$ on PEE

Special case:
Production technology $\rightarrow$ 14 countries’ PEE smaller
Results, PEE and PEM

- Improvement in emission intensity $\rightarrow$ PEE and PEM decrease
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Large positive effects from
- overall level of final demand $q \rightarrow q^r$ on PEM and $q^{-r}$ on PEE

Special case:
- Production technology $\rightarrow$ 14 countries’ PEE smaller

Eastern European countries: Estonia, Romania, Slovak Republic, Hungary, and Lithuania
Results, PEE and PEM

Improvement in emission intensity → PEE and PEM decrease
Final demand → PEE and PEM increase
  final demand effect partly offset by efficiency effect
Production technology → PEM increase, PEE

Large positive effects from
  overall level of final demand $q → q^r$ on PEM and $q^{-r}$ on PEE

Special case:
China

  PEE ($V_{2009}/V_{1995} = 3.52$) → trade shifts in foreign countries ($T^{-r}$&$d^{-r}$)
  PEM ($V_{2009}/V_{1995} = 7.03$) → increase in domestic final demand ($q^r$)
Results, PEE and PEM

Improvement in emission intensity → PEE and PEM decrease
Final demand → PEE and PEM increase
  final demand effect partly offset by efficiency effect
Production technology → PEM increase, PEE

Large positive effects from
  overall level of final demand q → q primer on PEM and q dash on PEE

Special case:
Japan
  level of domestic final demand (q primer) → decrease

PEM ($V_{2009}/V_{1995} = 0.90$)
Results, PEE and PEM

- Improvement in emission intensity → PEE and PEM decrease
- Final demand → PEE and PEM increase
  - Final demand effect partly offset by efficiency effect
- Production technology → PEM increase, PEE

Large positive effects from
- Overall level of final demand $q → q^r$ on PEM and $q^{-r}$ on PEE

Special case:
- Indonesia
  - Efficiency is decreased → change in emission intensity
    PEE ($V_{2009}/V_{1995} = 1.07$)
Results, PEE and PEM

Improvement in emission intensity → PEE and PEM decrease
Final demand → PEE and PEM increase
  final demand effect partly offset by efficiency effect
Production technology → PEM increase, PEE

Large positive effects from
  overall level of final demand $q → q_r$ on PEM and $q^{-r}$ on PEE

Special case:
Indonesia
  efficiency is decreased → change in emission intensity
  PEE ($V_{2009}/V_{1995} = 1.07$)
  emission intensity increased by more than 100% in 8 sectors:
  Textiles, Machinery, Electrical Equipment, Transport Equipment, Manufacturing
Conclusions, PTT

Improvement in emission intensity → PEE and PEM decrease
→ about ½ of countries’ PTT increase
Conclusions, PTT

Improvement in emission intensity → PEE and PEM decrease
→ about ½ of countries’ PTT increase

Final demand
→ PEE and PEM increase
→ effects on PEM are larger in 5/8 countries
→ 5/8 countries’ PTT decrease
Conclusions, PTT

Improvement in emission intensity → PEE and PEM decrease
  → about ½ of countries’ PTT increase

Final demand
  → PEE and PEM increase
  → effects on PEM are larger in 5/8 countries
  → 5/8 countries’ PTT decrease

Production technology
  → PEM increase, PEE
  → PTT decrease in 4/5 countries
Conclusions, PTT

Improvement in emission intensity → PEE and PEM decrease
  → about ½ of countries’ PTT increase

Final demand
  → PEE and PEM increase
  → effects on PEM are larger in 5/8 countries
  → 5/8 countries’ PTT decrease

Production technology
  → PEM increase, PEE
  → PTT decrease in 4/5 countries

Subcategories:
  \( d^r \) and \( q^r \) → PEM increase, no effect PEE → PTT decrease
  \( T^r \) and \( H^r \) → PEM increase → PTT decrease
Conclusions, PTT

Improvement in emission intensity → PEE and PEM decrease
→ about ½ of countries’ PTT increase

Final demand
→ PEE and PEM increase
→ effects on PEM are larger in 5/8 countries
→ 5/8 countries’ PTT decrease

Production technology
→ PEM increase, PEE
→ PTT decrease in 4/5 countries

Special case:
Romania’s PTT decreased by 73%
Conclusions, PTT

Improvement in emission intensity → PEE and PEM decrease
→ about ½ of countries’ PTT increase

Final demand
→ PEE and PEM increase
→ effects on PEM are larger in 5/8 countries
→ 5/8 countries’ PTT decrease

Production technology
→ PEM increase, PEE
→ PTT decrease in 4/5 countries

Special case:
Romania’s PTT decreased by 73%
→ PEE reduced by 50% (cleaner technology and smaller emission intensity in home country)
→ PEM increased by more than 200% (higher level of domestic final demand)
Thank you for your attention!

yan.xu@rug.nl
### Results, production technology

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>T</th>
<th>H</th>
<th>Tr</th>
<th>T-r</th>
<th>Hr</th>
<th>H-r</th>
<th>total</th>
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<td>29+ 11-</td>
<td>24+ 16-</td>
<td>15+ 25-</td>
<td>30+ 10-</td>
<td>18+ 22-</td>
<td>34+ 6-</td>
<td>32+ 8-</td>
</tr>
<tr>
<td><strong>PEM</strong></td>
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<td>36+ 4-</td>
<td>38+ 2-</td>
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<td>+</td>
<td>37+ 3-</td>
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<td>+</td>
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<td><strong>PTT</strong></td>
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<td>16+ 24-</td>
<td>7+ 33-</td>
<td>5+ 35-</td>
<td>27+ 13-</td>
<td>3+ 37-</td>
<td>27+ 17-</td>
<td>11+ 29-</td>
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**Total number of countries, \(n = 40\)**
Results, final demand

<table>
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<tr>
<th></th>
<th>F</th>
<th>d</th>
<th>q</th>
<th>dr</th>
<th>d-r</th>
<th>qr</th>
<th>q-r</th>
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<tr>
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<td>30+</td>
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<td>30+</td>
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<td>21-</td>
<td>5+</td>
<td>35-</td>
<td>31+</td>
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Total number of countries, \( n = 40 \)