Peeling the Onion:
Analyzing Aggregate, National and Sectoral
Energy Intensity in the European Union
An Application of the WIOD Database

Michael Schymura and Andreas Löschel
Centre for European Economic Research (ZEW), Mannheim, Germany
at
WIOD Final Conference, Groningen

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Outline

1. Motivation and Research Question
2. Research Approach
3. Part I: Index Decomposition Analysis
4. Part II: Empirical Investigation
5. Conclusion
Motivation and Research Question

Introductory Graphs for the EU27-Aggregate

(a) Gross Output
(b) Energy Use
(c) Energy Intensity

Figure: Gross Output, Energy Use and Energy Intensity in the EU27

What do these figures tell us?
- Shift in the composition of the aggregated European economy?
- Technology?
- Regulation, prices, country specific characteristics?
Motivation and Research Question

Introductory Graphs for the EU27-Aggregate

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What do these figures tell us?

- Shift in the composition of the aggregated European economy?
- Technology?
- Regulation, prices, country specific characteristics?
- Research Question: What are the drivers of this cleanup?
Our Approach

1. *Index Decomposition Analysis*
   - For the EU27 Aggregate
   - For all 27 European countries

2. *Construction of variables to control for:*
   - Technological Change
   - Energy Prices
   - Structural Change & Trade
   - Environmental Regulation
   - Country Characteristics

3. *Econometric analysis of index values and controls:*
   - Cross-Section and Panel Regressions to sort out causalities
   - Various types of estimation procedures
Conceptual Issues

Logarithmic Mean Divisa Index Decomposition (LMDI):

\[ D_{EI,Tot} = D_{EI,Str} D_{EI,Int} \]  \hspace{1cm} (1)

- \( D_{EI,Str} \) is the estimated impacts of *structural change* on the aggregate energy intensity
- \( D_{EI,Int} \) is the estimated impacts of changes in the energy intensity which can partly be explained by efficiency changes

\[ D_{Str} = \exp \left( \sum_i \frac{L(\omega_i,T,\omega_i,0)}{\sum_i L(\omega_i,T,\omega_i,0)} \ln \left( \frac{S_{i,T}}{S_{i,0}} \right) \right) \]  \hspace{1cm} (2)

\[ D_{Int} = \exp \left( \sum_i \frac{L(\omega_i,T,\omega_i,0)}{\sum_i L(\omega_i,T,\omega_i,0)} \ln \left( \frac{I_{i,T}}{I_{i,0}} \right) \right) \]  \hspace{1cm} (3)

with the logarithmic mean defined as

\[ L(\omega_i,2006,\omega_i,2005) = \frac{\omega_i,2006 - \omega_i,2005}{\ln \left( \frac{\omega_i,2005}{\omega_i,2006} \right)} \]  \hspace{1cm} (4)
Figure: Log Mean Divisia Index Decomposition of Energy Intensity

- How does the picture(s) look like when individual countries are introduced?
Two Exemplary Countries

- Structure became more energy-intensive in Germany
- Technology almost unaltered in Czech Republic
- We have performed IDA for all 27 European Countries
Factors we control for

- Panel of 27 European Countries, 1995 - 2009
- 3 dependent variables: Index values for total, structural and technology effect

1. Technology Factors: Total Factor Productivity (TFP), Income, Capital Vintaging, Energy Prices
   - WIOD, Barro and Lee (2010), Penn World Tables 7.0, Mincerian Returns on Education, Eurostat

2. Structural Factors: Trade Openness, Capital-to-Labor ratios
   - WIOD, CIA World Fact Book, Penn World Tables

3. Political Factors: Regulation
   - Constructed Policy Index of > 3000 energy policies in the 27 countries (together with FEEM)

   - CIA World Fact Book, Penn World Tables, Eurostat
### Part II: Empirical Investigation

#### Results (Detailed)

**Figure: Log Mean Divisia Index Decomposition of Energy Intensity**

**Table: Log Mean Divisia Index Decomposition of Energy Intensity**

<table>
<thead>
<tr>
<th>DEPENDENT VARIABLE:</th>
<th>TOTAL EFFECT</th>
<th>STRUCTURAL EFFECT</th>
<th>TECHNOLOGY EFFECT</th>
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<tbody>
<tr>
<td>Index Value</td>
<td>Coef.</td>
<td>z</td>
<td>Coef.</td>
</tr>
<tr>
<td>Instrumented Per Capita Income (logarithmic)</td>
<td>-2.236*</td>
<td>-2.43</td>
<td>3.997*</td>
</tr>
<tr>
<td>Instrumented Per Capita Income Squared (logarithmic)</td>
<td>0.088*</td>
<td>2.08</td>
<td>-0.213*</td>
</tr>
<tr>
<td>Instrumented Trade Openness</td>
<td>0.000</td>
<td>0.40</td>
<td>-0.001</td>
</tr>
<tr>
<td>Capital to Labor Ratio (logarithmic)</td>
<td>0.391**</td>
<td>2.34</td>
<td>-1.217**</td>
</tr>
<tr>
<td>Capital to Labor Ratio Squared (logarithmic)</td>
<td>-0.025</td>
<td>-1.43</td>
<td>0.151***</td>
</tr>
<tr>
<td>D.Estimated Total Factor Productivity (logarithmic)</td>
<td>0.018</td>
<td>0.94</td>
<td>0.043</td>
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<tr>
<td>Capital Vintaging (logarithmic)</td>
<td>0.032</td>
<td>0.85</td>
<td>0.027</td>
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<tr>
<td>REGUL</td>
<td>-0.000</td>
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<td>-0.015</td>
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<tr>
<td>EU15</td>
<td>0.150***</td>
<td>3.44</td>
<td>0.135</td>
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<tr>
<td>Geographical Latitude</td>
<td>-0.005***</td>
<td>-6.49</td>
<td>-0.000</td>
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<tr>
<td>Area in km2 (logarithmic)</td>
<td>-0.029</td>
<td>-1.85</td>
<td>-0.042</td>
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<tr>
<td>Population Growth</td>
<td>0.071</td>
<td>1.23</td>
<td>-0.072</td>
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<tr>
<td>Heating Degree Days (logarithmic)</td>
<td>0.058</td>
<td>0.106</td>
<td>-0.106</td>
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<tr>
<td>Energy Price (logarithmic)</td>
<td>-0.052*</td>
<td>-2.05</td>
<td>-0.153**</td>
</tr>
</tbody>
</table>

**Model Summary:**

- **Time Fixed Effects:** Yes
- **N:** 312
- \( R^2(\text{overall}) \): 0.788
- \( R^2(\text{between}) \): 0.789
- \( R^2(\text{within}) \): 0.781

* p<0.10, ** p<0.05, *** p<0.01; robust standard errors appear in parentheses; a constant is included in all regressions.
### Results (Schematic)

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>TFP</td>
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<tr>
<td>Vintaging</td>
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<tr>
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<td>✓</td>
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<tr>
<td>Income</td>
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<td>✓</td>
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<tr>
<td>Cap.-Lab.</td>
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<td>‡</td>
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<tr>
<td>EU15</td>
<td>‡</td>
<td>‡</td>
<td>‡</td>
</tr>
</tbody>
</table>
Some tentative conclusions

- Extensive study of European energy intensity
- Usage of WIOD and combination with established data sets
- Very large heterogeneity in Europe
- Decline due to improving technology
- Positive effects from European integration

Thank you for your attention!