Give credit where credit is due: Tracing value added in global production chains

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Presentation outline

• Global value chain: nature and measures
• Conceptual framework
  – Model setup and three important matrices
  – Major value-added components of gross exports
• Empirical results
  – Graphically show positions of countries in global value chains
• Database improvements and limitations
  – Extensions of the GTAP database
Contributions

• Conceptual framework
  – Unified
    • Incorporates all major measures in the literature
    • Vertical specialization and value-added trade
  – Complete
    • Decomposes gross exports into value-added components

• Empirical results
  – Informative:
    • Highlight each country’s upstream and downstream position
    • Caveat: Highlight differences but do not examine causes

• Database development
  – Improved measures of imported intermediate inputs and processing trade
Value chains, from a product view to a global view

• What is a global value chain?
  – A system of value-added sources and destinations within a globally integrated production network

• Literature
  – Asian regional chains: Pula and Peltonen (2009); Wang, Powers, and Wei (2009)
  – Global time series: Erumban et al. (2010); Wang et al. (2010)
Global value chains: Multiple measures

- Hummels, Ishii, and Yi (2001) measures of vertical trade
  - VS: share of imported inputs in exports
  - VS1: share of exports sent indirectly through third countries
- Newer measures
  - VAX: domestic value-added in exports (Johnson and Noguera, 2010):
  - VS1*: domestic value-added that returns home (Daudin et al., 2010)
- Not previously unified in a fully specified framework
Value chains in a two-country world:
Gross output

- All output is used as an intermediate or final good at home or abroad

\[ X_r = A_{rr}X_r + A_{rs}X_s + Y_{rr} + Y_{rs} \]

with \( N \) goods,

- \( X_r \): \((N \times 1)\) Gross output of country \( r \)
- \( A_{rs} \): \((N \times N)\) IO Coefficient matrix giving use in country \( s \) of intermediates from \( r \)
- \( Y_{rs} \): \((N \times 1)\) Final demand: Country \( s \)'s use of final goods from country \( r \)
Production system in a two-country world

- In block matrix notation

\[
\begin{bmatrix}
X_1 \\
X_2
\end{bmatrix} =
\begin{bmatrix}
A_{11} & A_{12} \\
A_{21} & A_{22}
\end{bmatrix}
\begin{bmatrix}
X_1 \\
X_2
\end{bmatrix} +
\begin{bmatrix}
Y_{11} + Y_{12} \\
Y_{21} + Y_{22}
\end{bmatrix}
\]

- Rearranging,

\[
\begin{bmatrix}
X_1 \\
X_2
\end{bmatrix} =
\begin{bmatrix}
I - A_{11} & -A_{12} \\
-A_{21} & I - A_{22}
\end{bmatrix}^{-1}
\begin{bmatrix}
Y_{11} + Y_{12} \\
Y_{21} + Y_{22}
\end{bmatrix} =
\begin{bmatrix}
B_{11} & B_{12} \\
B_{21} & B_{22}
\end{bmatrix}
\begin{bmatrix}
Y_1 \\
Y_2
\end{bmatrix}
\]

where

- \(B_{sr}\): \((N \times N)\) block Leontief inverse matrix, denoting the amount of total output in \(s\) required for a one-unit increase in final demand in country \(r\)
- \(Y_r\): \((N \times 1)\) vector of global use of \(r\)'s final goods
Value added in production

- Direct domestic value added in production:
  \[ V_1 = u[I - A_{11} - A_{21}] \quad \text{and} \quad V_2 = u[I - A_{12} - A_{22}] \]
  where
  \( V_r: (1 \times N) \) domestic value-added coefficient vector;
  element \( v_{ri} = 1 - \) intermediate input share from all countries
  \( u: (1 \times N) \) vector of ones

- **Value-added shares** matrix \((2 \times 2N)\)
  \[
  VAS = VB = \begin{bmatrix}
  V_1B_{11} & V_1B_{12} \\
  V_2B_{21} & V_2B_{22}
  \end{bmatrix}
  \]

  VAS decomposes the value added in production of each sector in all countries
Value-added exports

- Exports (N×1) include both intermediate and final goods

\[ E_r = \sum_{s \neq r} E_{rs} = \sum_s (A_{rs}X_s + Y_{rs}) \]

- Use E (2N×2) to calculate national value-added exports

\[
E = \begin{bmatrix}
E_1 & 0 \\
0 & E_2
\end{bmatrix}
\]

(See paper for value-added exports at the product level)

- Value-added exports matrix (2×2)

\[
VASE = VBE = \begin{bmatrix}
V_1B_{11}E_1 & V_1B_{12}E_2 \\
V_2B_{21}E_1 & V_2B_{22}E_2
\end{bmatrix}
\]
Fully generalizable: Value added in many-country world

\[ X = (I - A)^{-1} Y = BY \]

Production and trade system:

\[ VAS = VB \]
\[ VAS_E = VBE \]

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Description</th>
<th>Dimension</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Gross output</td>
<td>GN×1</td>
<td>G countries</td>
</tr>
<tr>
<td>Y</td>
<td>Final demand</td>
<td>GN×1</td>
<td>N sectors</td>
</tr>
<tr>
<td>A</td>
<td>IO coefficient</td>
<td>GN×GN</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Gross exports</td>
<td>GN×G</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Leontief inverse</td>
<td>GN×GN</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Direct value-added coefficient</td>
<td>G×GN</td>
<td></td>
</tr>
<tr>
<td>VAS</td>
<td>Value-added share</td>
<td>G×G</td>
<td></td>
</tr>
<tr>
<td>VAS_E</td>
<td>Value-added exports</td>
<td>G×G</td>
<td></td>
</tr>
</tbody>
</table>
VAS_E incorporates all value-added measures

- Diagonal elements: Domestic value added in exports
- Off-diagonal elements: Foreign value added in exports
- Each column sums to unity
- Characterizes both direct and indirect value-added exports

\[
\begin{align*}
\text{Indirect (VS1):} & \quad \text{Country 1’s value added embodied in 2’s and 3’s exports} \\
\text{Direct (VS):} & \quad \text{Foreign value added from 2 and 3 embodied in country 1’s exports}
\end{align*}
\]
Further decomposition of value-added exports

- Exports (N×1) include both intermediate and final goods
- Some intermediates are consumed in s; some are sent elsewhere

\[ E_{rs} = Y_{rs} + A_{rs} X_{ss} + A_{rs} \sum_{s \neq t} X_{st} \]  

(1)

- Final goods
- Finished in s
- Processed in s;
- Consumed in s consumed elsewhere

- DV measures the total domestic value-added embodied in r's exports

\[ DV_r = V_r B_{rr} E_r \]  

(2)

- Further decomposition of value-added exports: combine (1) and (2)
Complete decomposition of gross exports

Gross exports

- Domestic value added in exports (VAX)
- Domestic value added that returns from abroad (VS1*)
- Foreign value added in exports (VS)

Exports consumed by direct importer

- Final goods
- Intermediate inputs

Indirect exports sent to third countries

- Final goods
- Intermediate inputs

Final goods

Intermediate inputs

Indirect value-added exports (VS1)

Further downstream

Further upstream in GVCs
Decomposition of gross exports

- Advanced economies
- Emerging Asia
- Asia NICs
- Other emerging

Legend:
- Domestic VA
- Domestic VA returned
- Foreign VA
Domestic value-added components: Share of gross exports

Asia has less VA in intermed’s sent directly to consumer

Canada and Mexico too
Domestic value-added components: Share of domestic value added

Share of Value-added Exports

- Japan
- EU 15
- United States
- Australia, New Zealand
- Canada
- EFTA
- South Asia
- China
- Rest of East Asia
- Vietnam
- India
- Thailand
- Indonesia
- Philippines
- Malaysia
- Korea
- Hong Kong
- Taiwan
- EU accession countries
- Brazil
- Rest Latin America
- South Africa
- Mexico
- Rest of the world
- Russian Federation
- World average

- Final goods
- Intermed's absorbed by direct importer
- Intermed's reexported as intermediates
- Intermed's reexported as final goods
Intermediates and final goods, shares of domestic value-added exports

- Sum of distance to sides is same for all points in triangle
- Triangle can represent shares of each component in DVA exports

For example, final goods account for only 11% of Russia’s DVA exports, and intermediates absorbed by direct exporter account for 55% (reliance on energy exports)
Intermediates and final goods, shares of domestic value-added exports

- Colors indicate country grouping: Advanced (red), Asian emerging and NIC (blue), Other emerging (green)

- Emerging Asia differs markedly from other emerging countries
  - More final goods
  - Lower intermeds to direct consumer
Structure of value-added exports: VS1/VS

- Measures position in GVC
  - Ratio of indirect intermediates exports to foreign content of exports
  - Higher values: more upstream
    - Greater value sent indirectly
    - Less foreign value in imports
- Shows that Asia is different
- But has problems
  - Doesn’t distinguish raw material exporters from large developed countries
  - Not a perfect measure of integration: Both VS1 and VS are high for some countries
Sectoral VS1 to total VS ratios

- Clearly delineates type of indirect exports
- But are services really so similar to manufacturing across countries?
Domestic and foreign value-added shares of gross exports

- Mexico, EU accession, and emerging Asia are most tightly integrated into GVCs

- Exports by major advanced countries are predominantly domestic manufacturing and services value added

Domestic value: Raw materials

Domestic value: Manufacturing and services

Foreign value (including VS1*)
Database development: Estimating a global Inter-Region IO table

- Start with 2004 GTAP global trade and production database
- But, IRIO requires additional detail on source and use of intermediate inputs and final goods (elements of $A_{rs}$)
- Add detail on processing imports for Mexico and China
- Use detailed trade data (HS 6-digit) to improve imported intermediate use coefficients
  - UN Broad economic classification (BEC) distinguishes intermediate inputs from final goods in imports from each source in each sector
  - Proportional method assumes the intermediate share in imports from each source is the same as in U.S. domestic supply
Why BEC is better than proportional assumption

Intermediates as a share of U.S. electronic machinery imports, 2004

Proportion method

- World (BEC)
- Rest of America
- Russian Federation
- South Africa
- REST OF THE WORLD
- EU 12
- Mexico
- Brazil
- South Asia
- India
- Philippines
- Rest of east asia
- Malaysia
- Indonesia
- China
- Thailand
- Viet Nam
- Taiwan
- Korea
- Hong Kong
- Canada
- EU 15
- Australia & New Zealand
- EFTA
- Japan

Share from US import use table (54.2%)
The role of end use classifications and their limitations

• End use classifications such as BEC can improve the accuracy of IO coefficients in IRIO table by giving better row total control for each block matrix in A.

• Proportionality assumptions must still be used to allocate intermediate inputs to each industry after they enter the importing country.
  – Industry-level estimates of value-added trade may be unreliable, despite their theoretical tractability
  – More reliable data collected by national agencies are needed to overcome this limitation.
Conclusions

• Big picture fairly complete
  – Can account for entirety of global gross exports
  – Can account for all value-added measures
  – See clear differences in regional integration
    • Asia > North America > Europe
• Next steps
  – Empirical analysis: determinants of differences
  – Better metrics of supply chain participation
  – Extension to sector-level analysis
    • Further estimation of imported intermediate use by sector
Value-added in imports and exports by source

Sources of value added in:  Imports  Exports

- Imports: Major advanced countries similar to each other and to Asia
- Exports: Major advanced countries similar to each other but not to NICs