A World Factory in Global Production Chains: Estimating Imported Value-added in China’s Exports

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China is extraordinarily open and increasingly so!

Chinese firms use a lot of imported inputs in the production for exports
Imported inputs reduce value added in exports

- The story of an iPod
- In trade statistics
  China’s export value = $150/unit
- Chinese value added = $4
  - Varian, 2008
Motivation: Why important to know the extent of imported value added (foreign content) in exports
- Motivations and the literature

Conceptual Framework
- Problems with Existing Method
- A new method

Estimates of Foreign Content
- Foreign content in China’s total exports
- by sector

Further Splitting Foreign Content by Sources of Countries

Conclusions and Future Research
Motivations: Accurate knowledge of domestic content in Chinese exports is important for many questions.

- Effect of a Chinese yuan revaluation on trade surplus

- Trade balance in value added ≠ reported trade balance

- Effect of trade on skill premium/income inequality in Europe and the United States

- Effect of high oil price on global trade
  - Krugman’s NY Times blog June 21, 2008
How to compute foreign content in exports?

Existing Literature

- **International Trade: “vertical specialization”**
  - Hummels, Ishii and Yi (JIE, 2001) - HIY for short
  - Yi (JPE, 2003)
  - Goh and Olivier (HEC France wp, 2004)
  - Chinn (NBER wp, 2005)
  - U.S. National Research Council (Nat Acad Press, 2006)
  - Dean, Fung and Wang (ITC wp, 2007)

- **Input-output models: “domestic/foreign content”**
How to compute foreign (and domestic) content in exports?

- The HIY approach assumes the same intensity in the use of imported inputs between all exports and domestic sales.

- Probably not appropriate for most countries
  - “Duty drawback” -> use of more imported inputs in exports
  - Mexico: Maquiladora

- Especially inappropriate for China due to pervasive “processing exports” – exports that use a lot of imported inputs which receive duty free treatment
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企业负责人签名: [签名]

[加盖公章]
How to compute foreign/domestic content in exports?

- Need to develop a new approach

- **Step 1: Recognize processing exports explicitly**
  - Separate tracks of input-output coefficients for processing exports vs for normal exports and domestic sales
  - Challenge: the new input-output coefficient matrices not collected by authorities

- **Step 2: Estimate the new I/O coefficients**
  - Combine info from trade statistics with existing I/O tables
Objective of This Paper

- Discuss a new approach when processing exports are pervasive

- Develop a method to estimate unobserved input/output coefficients (for processing exports vs. normal exports/domestic sales)

- Apply the methodology to Chinese exports
  - Aggregate exports
  - Compare with the HIY’s methodology
  - By sector and by firm ownership
The I/O model when processing exports are not explicitly recognized - the implicit approach by HIY

(1) \[ A^D X + Y^D = X \]  
Total production = dom sale + exports

(2) \[ A^M X + Y^M = M \]  
Total imports = final sale + use as intermediates

(3) \[ uA^D + uA^M + A_v = u \]  
Total cost of production = direct VA(cost of factors) + cost of intermediates

\[ AD = [a^D_{ij}] = \text{matrix of direct input coefficients of domestic products}; \]
\[ AM = [a^M_{ij}] = \text{is an matrix of direct input coefficients of imported goods}; \]
\[ A^D = [a^D_{ij}] = \text{matrix of direct input coefficients of domestic products}; \]
\[ A^M = [a^M_{ij}] \] is an \text{matrix of direct input coefficients of imported goods};
\[ Y^D = \text{vector of final demands for domestically produced products, including usage in gross capital formation, private and public consumption, and gross exports}; \]
\[ Y^M = \text{vector of final demands for imported products, including usages in gross capital formation, private and public final consumption}; \]
\[ X \] is a \text{vector of gross output};
\[ M \] is a \text{vector of imports};
\[ A^v = [a^v_{ij}] \] is a \text{vector of each sector j’s ratio of value-added to gross output};
The I/O model when processing exports are not explicitly recognized - the implicit approach by HIY

The solution:

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

\[ \Delta(M - Y^M) = A^M (I - A^D)^{-1} \Delta Y^D \]

\[ DVS = \hat{A}_v \Delta X / \Delta Y^D = \hat{A}_v (I - A^D)^{-1} \]

\( Y^D \) is a vector of final demands for domestic products, which includes domestic products used in gross capital formation, private and public final consumption, and gross exports;
Define share of domestic value in exports

- Define share of domestic content (domestic value added) in final demand:

\[ DVS = \frac{\Delta V}{\Delta Y^D} = \frac{\hat{A}_v \Delta X}{\Delta Y^D} = \frac{\hat{A}_v (I - A^D)^{-1}} \]

- Share of foreign content:
- FVA = 1 - DVA
Intuition behind the DVA share formula:

\[ DVS = A_v + A_v A^D + A_v A^D A^D + A_v A^D A^D A^D + \ldots \]

\[ = A_v (I + A^D + A^D^2 + A^D^3 + \ldots) \]

- The matrix power series converges

Total DVA Share in a country’s exports by industry

\[ DVS = A_v (I - A^D)^{-1} \]
Define share of foreign value in exports

- Define share of foreign content (FVS):

\[ FVS = u - DVS = u - \hat{A}_v (I - A^D)^{-1} \]

\[ = u A^M [I-A^D]^{-1} \]

\[ = HIY’s \text{ Vertical Specialization share} \]
Assessing DVA/FVA when processing trade is pervasive: New approach

- Existing approach:
  - Domestic final demand and all exports are assumed to have the same input-output matrix.

- New approach
  - Recognize processing exports.
  - Let processing exports have a potentially different I/O matrix (while still letting normal exports and domestic final demand to have the same matrix).

This is not a trivial extension.
Re-think the “traditional” model equation by equation

(1) \[ A^D X + Y^D = X \]

Total production = dom sale + exports

(2) \[ A^M X + Y^M = M \]

Total imports = final sale + use as intermediates

(3) \[ (A^D + A^M)'X + \hat{A}_v X = X \]

Total cost of production =
direct VA(cost of factors) +cost of intermediates

(4) \[ uA^D + uA^M + A_v = u \]

\[ AD = [a^D_{ij}] = \text{matrix of direct input coefficients of domestic products;} \]
\[ AM = [a^M_{ij}] \text{ is an matrix of direct input coefficients of imported goods;} \]
\[ A_{DD}^{dd} = \left[a_{ij}^{dd}\right] = \left[\frac{z_{ij}^{dd}}{x_j - e_j^p}\right], \quad A_{MD}^{md} = \left[a_{ij}^{md}\right] = \left[\frac{z_{ij}^{md}}{x_j - e_j^p}\right], \quad A_v^D = \left[a_{j}^{vd}\right] = \left[\frac{v_j^d}{x_j - e_j^p}\right] \]

\[ A_{DP}^{dp} = \left[a_{ij}^{dp}\right] = \left[\frac{z_{ij}^{dp}}{e_j^p}\right], \quad A_{MP}^{mp} = \left[a_{ij}^{mp}\right] = \left[\frac{z_{ij}^{mp}}{e_j^p}\right], \quad A_v^P = \left[a_{j}^{vp}\right] = \left[\frac{v_j^p}{e_j^p}\right] \]

A and Z matrices and linear transformation of each other
## IO table with separate account for processing trade

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<th>Final use</th>
<th>Gross Output or Imports</th>
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<td>Production of processing exports</td>
<td>Final use C+I+G+E</td>
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<td>$V^P$</td>
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<td>$X-E^P$</td>
<td>$E^P$</td>
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Re-worked model when processing trade is recognized

\[(1^*)\quad A^{DD}(X - E^P) + A^{DP}E^P + Y^D = X\]

\[(2^*)\quad A^{MD}(X - E^P) + A^{MP}E^P + Y^M = M\]

\[(3^*)\quad (A^{DP} + A^{MP})'E^P + \hat{A}^P_v E^P = E^P\]

\[(4^*)\quad (A^{DD} + A^{MD})'(X - E^P) + \hat{A}^D_v (X - E^P) = X - E^P\]

\[(5^*)\quad uA^{Dk} + uA^{Mk} + A_v = u, \quad k = D, P\]
Total imported intermediate inputs request:

\[ M - Y^M = A^{MD} (I - A^{DD})^{-1} (Y^D + E^N) + A^{MD} (1 - A^{DD})^{-1} A^{DP} E^P + A^{MP} E^P \]

Total FVA(VS) share in a country’s exports by industry

\[
\begin{bmatrix}
VSS^D \\
VSS^P
\end{bmatrix}^T = \begin{bmatrix}
u A^{MD} (I - A^{DD})^{-1} \\
u A^{MD} (1 - A^{DD})^{-1} A^{DP} + u A^{MP}
\end{bmatrix}^T
\]

Total FVA (VS) share in a country’s aggregate exports

\[
TVSS = u A^{MD} (I - A^{DD})^{-1} \frac{E^N}{te} + u (A^{MD} (1 - A^{DD})^{-1} A^{DP} + A^{MP}) \frac{E^P}{te}
\]
This is a generalization of HIY(2001)

- When $A^{DP} = A^{DD}$, and $A^{MP} = A^{MD}$,
  - TVSS reduces to the HIY formula

- When $E^P/te = 0$,
  - TVSS also reduces to the HIY formula
Domestic content/DVA: generalizes the HIY formula

Total DVA share in a country’s exports by industry

\[
\overline{DVS} = \left[\begin{array}{c} DVS_D^T \\ DVS_P^T \end{array} \right] = \left[\begin{array}{c} A_V^D (I - A^{DD})^{-1} \\ A_V^D (1 - A^{DD})^{-1} A^{DP} + A_V^P \end{array} \right]^T
\]

Total DVA share in a country’s aggregate exports

\[
TDVS = A_V^D (I - A^{DD})^{-1} \frac{E_N}{te} + (A_V^D (1 - A^{DD})^{-1} A^{DP} + A_V^P) \frac{E_P}{te}
\]
This is a generalization of HIY(2001)

When $A^{DP}=A^{DD}$, and $A^{MP}=A^{MD}$,
- TDVS reduces to 1- HIY’s VS

When $E^{P}/te = 0$,
- TDVS also reduces to 1-HIY’s VS
Estimation results

- Aggregate
- By industry
Chinese imported value added is approximately half of its manufacturing exports.
Foreign content is much higher in processing exports than in normal exports.
Hummel, Ishii and Yi’s formula:
1. Level of foreign content is substantially under-estimated;
2. “Trend” in FVA is most likely incorrect
Why doesn’t domestic content in exports rise over time?

Two opposing forces

- Domestic input producers get better over time
- But the cost of using imported inputs may get lower over time
Decomposing Chinese Total Manufacturing Exports

Differences between HIY and redefined measures

![Chart showing the decomposition of Chinese total manufacturing exports with categories for direct domestic, indirect domestic, direct foreign, and indirect foreign value-added for different years.](chart.png)
Domestic Content by Manufacturing Sector
Selected Low DVA (or high foreign content) share industries, in percent, 2002

Electronic computer
Telecommunication equipment
Cultural and office equipment
Other computer peripheral equipment
Electronic element and device
Radio, television and communication
Household electric appliances
Plastic products
Generators
Instruments, meters and other measuring
Printing, reproduction of recording media
Other electric machinery and equipment
Leather, fur, down and related products

Share as China’s exports to the World
DVA as share of Chinese exports
Processing exports as share of Chinese exports
Domestic Content in Manufacture Exports (2)
Selected Medium DVA share industries, in percent, 2002

- Toys, sporting and athletic and recreation
- Arts and crafts products
- Special chemical products
- Petroleum and nuclear processing
- Ship building
- Metal products
- Paper and paper products
- Other general industrial machinery
- Nonferrous metal smelting
- Other transport equipment
- Rubber products
- Other manufacturing products
- Steel-smelting

Share as China’s exports to the World
DVA as share of Chinese exports
Processing exports as share of Chinese exports
Domestic Content by Manufacture Sector (3)
Selected High DVA (low foreign content) share industries, in %, 2002

- Chemical fibers
- Paints, varnishes and similar coatings, printing ink and mastics
- Woollen textiles
- Knitted and crocheted fabrics and articles
- Alloy iron smelting
- Textiles production
- Boiler, engines and turbine
- Railroad transport equipment
- Furniture
- Products of wood, bamboo, cane, palm, straw
- Basic chemicals
- Medical and pharmaceutical products
- Hemp textiles
- Metalworking machinery
- Steel pressing
- Chemical fertilizers
- Other non-metallic mineral products
- Coking

Legend:
- Processing exports as share of Chinese exports
- DVA as share of Chinese exports
- Share as China’s exports to the World
Slicing Up the Value Chain along Multiple Countries: Methodology

- Decompose foreign content further into value added from separate key foreign countries

- iPod Example: Japan, Korea, Taiwan, US, etc
**Methodology**

- Assuming \( G \) countries = \( M + (G-M) \)
- and \( N \) sectors
- Example: 2 sectors, 3 countries (\( M=2, \ G-M=1 \))

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The model with an Inter-regional Input-output Table

\( \sum_{s=1}^{M} \sum_{j=1}^{N} z_{ij}^{sr} + \sum_{s=1}^{M} \sum_{k=1}^{H} y_{ik}^{sr} + \sum_{s=G-M}^{G} e_{i}^{sr} = x_{i}^{r} \)  

Total production = dom sale + exports

\( \sum_{s=1}^{M} \sum_{i=1}^{N} z_{ij}^{sr} + \sum_{s=G-M}^{G} \sum_{i=1}^{N} m_{ij}^{sr} + v_{j}^{r} = x_{j}^{r} \)  

Total cost of production = direct VA(cost of factors) + cost of intermediates
Decomposing value-added into sources along multiple countries/sectors

- The computation is similar to a single country case, except that the relevant I/O coefficient matrix is different

\[ DVS = \frac{\Delta V}{\Delta Y^D} = \hat{A}_v \frac{\Delta X}{\Delta Y^D} = \hat{A}_v (I - A^D)^{-1} \]

**Gain:** value added from multiple countries

**Shortcoming:** no information on processing vs normal trade; potentially under-estimating FVA as a whole
What do we do?

For the split between and foreign and domestic content, we maintain the estimates from the first part of the paper (i.e., KWW).

We split foreign content further by source countries by making use of the inter-regional I/O table.
### Tracing Foreign Value Added to Sources (China’s Exports to the U.S.)

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<th>Korea (5)</th>
<th>Malaysia (6)</th>
<th>Taiwan (7)</th>
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<th>United States (11)</th>
<th>Hong Kong (12)</th>
<th>Rest of World (13)</th>
<th>Total (14)</th>
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<td>51.3</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>2000</td>
<td>1.6</td>
<td>15.5</td>
<td>8.4</td>
<td>1.6</td>
<td>7.9</td>
<td>0.5</td>
<td>1.2</td>
<td>1</td>
<td>8.9</td>
<td>10.5</td>
<td>42.9</td>
<td>100</td>
</tr>
</tbody>
</table>

1. Japan, US, Hong Kong, Korea, and Taiwan are major suppliers of components to China’s exports
2. The role of HK has declined substantially over time
## Slicing up value chains for the top exporting sectors

<table>
<thead>
<tr>
<th>Industries</th>
<th>Export Value in 2002 (in million dollars)</th>
<th>Share in ‘s Manuf. Exports (%)</th>
<th>Share of processing exports (%)</th>
<th>Domestic Content Share (%)</th>
<th>Foreign Content Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Television, radios, audios &amp; communication equipment</td>
<td>32,713</td>
<td>10.2</td>
<td>89.8</td>
<td>35.0</td>
<td>65.0</td>
</tr>
<tr>
<td>Electronic computing equipment</td>
<td>22,450</td>
<td>7.0</td>
<td>99.1</td>
<td>16.9</td>
<td>83.1</td>
</tr>
<tr>
<td>Wearing apparel</td>
<td>22,450</td>
<td>7.0</td>
<td>45.1</td>
<td>67.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Knitting</td>
<td>18,601</td>
<td>5.8</td>
<td>31.6</td>
<td>72.9</td>
<td>27.1</td>
</tr>
<tr>
<td>Lighting fixtures, batteries, wiring and others</td>
<td>17,960</td>
<td>5.6</td>
<td>66.8</td>
<td>46.1</td>
<td>53.9</td>
</tr>
<tr>
<td>Other manufacturing products</td>
<td>16,036</td>
<td>5.0</td>
<td>64.2</td>
<td>55.0</td>
<td>45.0</td>
</tr>
<tr>
<td>Leather and leather products</td>
<td>14,432</td>
<td>4.5</td>
<td>54.3</td>
<td>48.8</td>
<td>51.2</td>
</tr>
<tr>
<td>Metal products</td>
<td>14,111</td>
<td>4.4</td>
<td>43.2</td>
<td>57.9</td>
<td>42.1</td>
</tr>
<tr>
<td>Other electronics and electronic products</td>
<td>13,791</td>
<td>4.3</td>
<td>93.4</td>
<td>19.2</td>
<td>80.8</td>
</tr>
<tr>
<td>General machinery</td>
<td>11,225</td>
<td>3.5</td>
<td>43.7</td>
<td>58.5</td>
<td>41.5</td>
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<tr>
<td>Semiconductors and integrated circuits</td>
<td>10,904</td>
<td>3.4</td>
<td>89.7</td>
<td>22.2</td>
<td>77.8</td>
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<tr>
<td>Wooden furniture</td>
<td>8,980</td>
<td>2.8</td>
<td>36.7</td>
<td>76.3</td>
<td>23.7</td>
</tr>
<tr>
<td>Plastic products</td>
<td>7,697</td>
<td>2.4</td>
<td>64.5</td>
<td>37.6</td>
<td>62.4</td>
</tr>
</tbody>
</table>
## Sources of Foreign Value Added in 's Exports to the in 2000

### Industries

<table>
<thead>
<tr>
<th>Industries</th>
<th>Foreign Content Share (%)</th>
<th>Sources of Foreign Value Added in 's Exports to the in 2000</th>
<th>Japan</th>
<th>Korea</th>
<th>Taiwan</th>
<th>Singapore</th>
<th>Other ASEAN</th>
<th>US</th>
<th>HK</th>
<th>EU15</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Television, radios, audios &amp; communication equipment</td>
<td>65.0</td>
<td></td>
<td>16.2</td>
<td>7.2</td>
<td>7.8</td>
<td>1.8</td>
<td>4.6</td>
<td>11.1</td>
<td>16.9</td>
<td>16.5</td>
<td>17.8</td>
</tr>
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<td></td>
<td>15.9</td>
<td>7</td>
<td>8.3</td>
<td>2.6</td>
<td>6.5</td>
<td>12.6</td>
<td>16.5</td>
<td>13</td>
<td>17.6</td>
</tr>
<tr>
<td>Wearing apparel</td>
<td>33.0</td>
<td></td>
<td>19.4</td>
<td>10.6</td>
<td>10.3</td>
<td>0.6</td>
<td>3.9</td>
<td>6.1</td>
<td>7.3</td>
<td>9.7</td>
<td>32.1</td>
</tr>
<tr>
<td>Knitting</td>
<td>27.1</td>
<td></td>
<td>17</td>
<td>10.3</td>
<td>10</td>
<td>0.4</td>
<td>4.1</td>
<td>5.5</td>
<td>8.5</td>
<td>8.9</td>
<td>35.4</td>
</tr>
</tbody>
</table>
Conclusions

- Across all products, the average share of imported value added is about 50% for China.
  - No robust evidence of decline/increase after the WTO accession

- The FVA share varies across products
  - Relatively more sophisticated sectors are more likely to have a high FVA share (e.g., consumer electronics, 65%, and computers, 83%)

- For products with a high foreign content, Japan, Korea, Taiwan, Hong Kong and the U.S. are the primary contributors to foreign content
Thank you.