The Value-added Structure of Gross Exports and Global Production Network

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Presentation Outline

• Motivation
• Conceptual Framework: use a two country case to illustrate core ideas
  – Transparent: trade accounting framework in block matrix formulation
  – Complete: decompose a country's gross exports into five basic value-added components that can be estimated independently, including what is double counted, established a full concordance between value-added measures and official trade statistics;
  – Comprehensive: all existing measures in the literature and measures we newly defined can be derived in an unified math framework
• Empirical Results
  • Gross exports decomposition highlight regional differences in supply chain participation, structure of double counted value-added components in addition to value-added exports show different country’s position in global value chain;
  • Report RCA index computation based on gross exports and domestic value-added in exports to illustrate the potential of the framework to reshape our understanding of global trade.
Objective

• To discover the value-added structure of gross exports and establish a formal relationship between value-added measures and officially reported trade statistics, identifying those parts of value-added in gross trade statistics which is double counted, thus link official trade statistics to the SNA standard.

• Whether the double counted portion of official trade statistics contains useful information? Whether decompose value-added trade or global GDP alone will be enough to measure the degree of vertical specialization and a country’s position in the global production chains?

• Help policy makers and the public to understand what the official trade statistics really means, to avoid misleading conclusions.
Measure Domestic and Foreign Content in Exports: HIY measure of vertical specialization

- A country can participate in vertical specialization in TWO WAYS:
  - uses imported intermediate inputs to produce exports
  - exports intermediate goods that are used as inputs by another country to produce goods for exports

- Two measures of “vertical specialization”
  - VS: measure of the value of imported contents embodied in a country’s exports
  - VS1: measure of intermediate exports sent indirectly through other countries to final destination

- A complete picture of vertical specialization and a county’s position in a vertical integrated production network involves both measures.
Shortcomings of HIY Measures

Two key assumptions are needed for the standard HIY’s measure to accurately reflect domestic contents in exports:

• the intensity in the use of imported inputs is the same for goods are produced for export or for domestic final demand. This is not true for processing trade which is significant portion of exports for a large number of developing countries;

• all imported intermediate inputs are 100% foreign value added. HIY measure tends to over-estimate foreign value-added share thus underestimate domestic value-added share in exports. This particular important for developed countries since their imports often embodied a large share of its own value-added.
Newer Measures in Value-added Trade literature

- VS1*: domestic value-added in intermediates first exported then returns home in final goods imports (Daudin et al., 2010)
- Value-added exports or Value-added content of trade
  Value-added produced in source country $s$ but absorbed in destination country $r$ (Johnson and Noguera, 2010)
- VAX Ratio: Ratio of value-added exports to gross exports
- Value-added is a "net" concept, double counting is not allowed, while measures of vertical specialization involve values that show up in more than one country’s gross exports, so have to include some double-counted portions in trade statistics. More border crossing of intermediate goods (more double counting) means larger difference between these two type measures.
Conceptual Shortcomings of Existing Measures

- Measures of value-added trade and measures of vertical specialization are not equal each other in general but often used exchangebly in the literature;
- These existing measures were all proposed as stand-alone indicators. No common mathematical framework proposed in the literature provides a unified accounting for them and spells out their relationships;
- All measures proposed so far can not identify all value-added components in gross exports.
- To better understand the relationship of these two type measures, we need define them in math terms and drive them from a common framework.
Production and trade in a two-country world

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

\[ X_s = A_{ss} X_s + Y_{ss} + A_{sr} X_r + Y_{sr} \]  
(1)

- In block matrix notations

\[
\begin{bmatrix}
X_1 \\
X_2
\end{bmatrix} =
\begin{bmatrix}
A_{11} & A_{12} \\
A_{21} & A_{22}
\end{bmatrix}
\begin{bmatrix}
X_1 \\
X_2
\end{bmatrix} +
\begin{bmatrix}
Y_{11} + Y_{12} \\
Y_{21} + Y_{22}
\end{bmatrix}
\]  
(2)

- Rearrange

\[
\begin{bmatrix}
X_1 \\
X_2
\end{bmatrix} =
\begin{bmatrix}
I - A_{11} & -A_{12} \\
-A_{21} & I - A_{22}
\end{bmatrix}^{-1}
\begin{bmatrix}
Y_{11} + Y_{12} \\
Y_{21} + Y_{22}
\end{bmatrix} =
\begin{bmatrix}
B_{11} & B_{12} \\
B_{21} & B_{22}
\end{bmatrix}
\begin{bmatrix}
Y_1 \\
Y_2
\end{bmatrix}
\]  
(3)

\(B_{sr}\): Elements in Leontief inverse matrix, measure the amount of gross output in \(s\) required for a one-unit increase in final demand at country \(r\)

\(Y_s\): Scalar, global use of country \(s\)’s final goods
Value added Share by Source of Production

• Direct domestic value added in production:
  \[ V_1 = u[I - A_{11} - A_{21}] \]
  where
  \[ V_r: \text{ direct domestic value-added coefficient;} \]
  \[ = 1 - \text{intermediate input share from both countries} \]

• Value-added shares matrix (2×2) decomposes value added production by source of each country into domestic and foreign value-added shares, determined by each country’s production technology

\[
VB = \begin{bmatrix} V_1B_{11} & V_1B_{12} \\ V_2B_{21} & V_2B_{22} \end{bmatrix} \quad V = \begin{bmatrix} V_1 & 0 \\ 0 & V_2 \end{bmatrix}
\]

\[ V_1B_{11} + V_2B_{21} = DCS_1 + FCS_1 = u \quad (4) \]
Gross Output Decomposition Matrix

- Decomposing each country's gross output to different geographical locations that sustain global final goods production:

\[
\begin{bmatrix}
X_{11} & X_{12} \\
X_{21} & X_{22}
\end{bmatrix} =
\begin{bmatrix}
B_{11} & B_{12} \\
B_{21} & B_{22}
\end{bmatrix}
\begin{bmatrix}
Y_{11} & Y_{12} \\
Y_{21} & Y_{22}
\end{bmatrix} =
\begin{bmatrix}
B_{11}Y_{11} + B_{12}Y_{21} & B_{11}Y_{12} + B_{12}Y_{22} \\
B_{21}Y_{11} + B_{22}Y_{21} & B_{21}Y_{12} + B_{22}Y_{22}
\end{bmatrix}
\]

- Not part of value-added exports, but part of domestic content in gross exports.
Value-added Trade

- \( Y_{sr} \) is a scalar and \( Y \) is the 2 by 2 final demand matrix.
- \( \hat{\lambda}_r \) is a 2 by 2 diagonal matrix with direct value-added coefficients along the diagonal.

\[
\hat{\lambda} Y = \begin{bmatrix}
\hat{\lambda}_1 & 0 \\
0 & \hat{\lambda}_2
\end{bmatrix}
\begin{bmatrix}
B_{11} & B_{12} \\
B_{21} & B_{22}
\end{bmatrix}
\begin{bmatrix}
Y_{11} & Y_{12} \\
Y_{21} & Y_{22}
\end{bmatrix}
\]

(6)

- Its off diagonal elements constitute the 2 by 2 bilateral value-added trade matrix:

\[
VT_{12} = V_1 X_{12} = V_1 B_{11} Y_{12} + V_1 B_{12} Y_{22}
\]

(7)
Gross Exports and its Value-added Components

- From equation (1) gross exports of country 1 are
  \[ E_{12} = Y_{12} + A_{12} X_2 \]  
  \( (8) \)
  
  \[ VA(Y_{12}) = V_1 B_{11} Y_{12} + V_2 B_{21} Y_{12} \]  
  \( (9) \)
  
  \[ VA(A_{12} X_2) = V_1 B_{11} A_{12} X_2 + V_2 B_{21} A_{12} X_2 \]  
  \( (10) \)

- First term of (11) includes two types of value-added:
  
  (1) \[ V_1 B_{12} E_{21} = V_1 B_{12} Y_{21} + V_1 B_{12} A_{21} X_1 \]  
  Country 1’s value added embodied in its imports from country 2
  
  (2) \[ V_1 B_{12} Y_{22} \]  
  Value added generated in Country 1 that is absorbed in 2 after being used as intermediate inputs by Country 2

- This also can be proved mathematically
Gross Exports and its Value-added Components

• Combine these six terms

\[ VA(E_{12}) = uE_{12} = (V_1B_{11} + V_2B_{21})(Y_{12} + A_{12}X_2) \]

\[ = V_1B_{11}Y_{12} + V_1B_{12}Y_{22} + V_1B_{12}Y_{12} + V_2B_{21}Y_{12} + V_1B_{12}A_{21}X_1 + V_2B_{21}A_{12}X_2 \]  \hspace{1cm} (11)

• Last two terms in (11) include double counted gross output due to intermediate goods trade. We know \( X_1 = Y_{11} + A_{11}X_1 + E_{12} \)

\[ X_1 - (I - A_{11})^{-1}Y_{11} = (I - A_{11})^{-1}E_{12} \]  \hspace{1cm} (12)

• Replace \( X_1 \) and \( X_2 \) in (11) by

\[ X_1 = (I - A_{11})^{-1}Y_{11} + X_1 - (I - A_{11})^{-1}Y_{11} \]  \hspace{1cm} (13)

\[ X_2 = (I - A_{22})^{-1}Y_{22} + X_2 - (I - A_{22})^{-1}Y_{22} \]  \hspace{1cm} (14)
Gross Exports and its Value-added Components

• A country’s gross exports can be decomposed into five basic value-added components:

\[ uE_{12} = V_1B_{11}Y_{12} + V_1B_{12}Y_{22} \quad (1) + (2) \text{ Value-added exports} \]

\[ + V_1[B_{12}Y_{21} + B_{12}A_{21}(I - A_{11})^{-1}Y_{11}] + V_1B_{12}A_{21}[X_1 - (I - A_{11})^{-1}Y_{11}] \quad (4) \]

\[ + V_2[B_{21}Y_{12} + B_{21}A_{12}(I - A_{22})^{-1}Y_{22}] + V_2B_{21}A_{12}[X_2 - (I - A_{22})^{-1}Y_{22}] \quad (5) \]

**Pure double counting measures**

• (4) is domestic value-added return home; (5) is foreign value-added in exports; the last term in (4) and (5) is double counted value-added in exports; the third country term is missing in two country case. Which is box (3) in graph in next slide.
Decomposition of Gross Exports: Concepts

Gross exports (E)

Domestic Content (DC)
- Exported in final goods (1) VT
- Exported in intermediates absorbed by direct importers (2) VT
  - Direct value-added exports (1)+(2)
- Exported in intermediates re-exported to third countries (3) VT
  - Indirect value-added exports (IV) (3)

Foreign Content (VS)
- Exported in intermediates that return in own imports (4) VS1*
- Exported in intermediates
  - Exported in final goods; Returned DV in final goods; Returned DV in intermediates pure double counted DV in intermediates
- Other countries’ DC
  - 5a. FV in final goods;
  - 5b. FV in intermediates
  - 5c. pure double counted FV in intermediates
Further Partition and Interpretation of the Double Counting Measures

- The pure double counting measure (the last term in (4) and (5)) can be rewritten in terms of final demand by replacing \( X_s \):
  \[
  V_1B_{12}A_{21}[X_1 - (I - A_{11})^{-1}Y_{11}] = V_1B_{12}A_{21}[B_{11}Y_{12} + B_{12}Y_{22} + B_{12}Y_{21} + B_{12}A_{21}(I - A_{11})^{-1}Y_{11}]
  \] (16)

- First three terms of equation (15)
  \[
  = V_1B_{11}Y_{12} + V_1B_{12}Y_{22} + V_1[B_{12}Y_{21} + B_{12}A_{21}(I - A_{11})^{-1}Y_{11}]
  \]

- When \( : \) occurs in two way intermediate goods trade, a part of the final gross output to sustain country 1's gross exports is double counted.

- How: exactly reflects the back and forth, double counting nature of intermediate goods trade.
Unify all Existing Measures in a Common Mathematical Framework

- First term in (4) is also labeled as VS1* by Daudin et al (2011).
- (5) is labeled as VS, and (3) + (4) is labeled as VS1 by HIY (2001).
- (4) and (5) involve value added that crosses national borders at least twice, and are the sources of multiple counting of value added in standard trade statistics.
- The share of domestic content in a country's exports equals (1) + (2) + (3) + (4)
- (1) + (2) + (3) divided by gross exports is the VAX ratio for each country’s exports to the world defined by Johnson and Noguera (2010).
Gross exports Decomposition and Measures of Vertical Specialization

• All measures of vertical specialization in the previous literature can be expressed and generalized as linear combination of the various value-added components accounted in our decomposition equation. For example:

\[ VS_1 = V_2 B_{21} E_{12} = V_2 [B_{21} Y_{12} + B_{21} A_{12} (I - A_{11})^{-1} Y_{22}] \]

\[ + V_2 B_{21} A_{12} [X_2 - (I - A_{22})^{-1} Y_{22}] = (u - V_1 B_{11}) E_{12} \]  \hspace{1cm} (16)

• In a single country IO model without two-way intermediate goods trade

\[ VS = u - A_v (I - A^D)^{-1} E = u A^M (I - A^D)^{-1} E \]  \hspace{1cm} (17)

• In two-country with two-way intermediate goods trade

\[ VS = \{u - V_s (I - A_{ss})^{-1} - V_s B_{sr} A_{rs} (I - A_{ss})^{-1}\} E_s = (u - V_s B_{ss}) E_s \]  \hspace{1cm} (18)
Conceptual Difference: Domestic Content and Value-added Exports

- Because VS share and $V_s B_{ss}$ sum to unity, it is natural to define the domestic content share in exports as $V_s B_{ss}$

$$DC_1 = V_1 B_{11} = VT_{12} + V_1 B_{12} Y_{21} + B_{12} A_{21} (I - A_{11})^{-1} Y_{11} + V_1 B_{12} A_{21} [X_1 - (I - A_{11})^{-1} Y_{11}]$$  (19)

- Value-added exports and domestic content in exports are two related, but different concepts. Both measure the value generated by factors employed in the source country, however, domestic content is independent of where that export value is used, while value-added trade depends on how a country’s exports are used by importers. It is the value-added generated by a country but absorbed by another country.
HIY VS is a special case of ours

\[
\begin{bmatrix}
B_{11} & B_{12} \\
B_{21} & B_{22}
\end{bmatrix}
= 
\begin{bmatrix}
(I - A_{11} - A_{12}(I - A_{22})^{-1}A_{21})^{-1} & B_{11}A_{12}(I - A_{22})^{-1} \\
(I_2 - A_{22})^{-1}A_{21}B_{11} & (I - A_{22} - A_{21}(I - A_{11})^{-1}A_{12})^{-1}
\end{bmatrix}
\]

\[
VS = \begin{bmatrix}
V_2 B_{21} E_{1*} \\
v_1 B_{12} E_{2*}
\end{bmatrix}
= \begin{bmatrix}
u(A_{21} - A_{12}(I - A_{22})^{-1}A_{21})(I - A_{11} - A_{12}(I - A_{22})^{-1}A_{21})^{-1} E_{1*} \\
u(A_{12} - A_{21}(I - A_{11})^{-1}A_{12})(I - A_{22} - A_{21}(I - A_{11})^{-1}A_{12})^{-1} E_{2*}
\end{bmatrix}
\]

\[
VS_{-HIY} = \begin{bmatrix}
u A_{21}(I - A_{11})^{-1} E_{1*} \\
u A_{12}(I - A_{22})^{-1} E_{2*}
\end{bmatrix}
\]

HIY measure only captures foreign content in gross exports when either \(A_{12} = 0\) or \(A_{21} = 0\); i.e., in the case when only one country’s intermediate goods are used abroad.
• Define \( E = \begin{bmatrix} \frac{E_1}{uE_1} & 0 & 0 \\ 0 & \frac{E_2}{uE_2} & 0 \\ 0 & 0 & \frac{E_3}{uE_3} \end{bmatrix} \) Multiply VB matrix with country’s exports structure at different aggregation level as weights, we could obtain various vertical specialization measures in the literature at different level. At the most aggregate level

Diagonal elements: domestic content share in exports
Off-diagonal elements: foreign content share in exports; Each column sum to unity

Domestic content share in exports (VAX ratio plus share of VS1*)

VS share: imported inputs from 2 and 3 embodied in country 1’s exports

VS1 share: Country 1’s exported intermediate goods embodied in 2’s and 3’s exports

3 by 3
Decomposition of Gross Exports
--Actual data, 2004

- About half of double counting in U.S. exports from its own value-added returns home via imports (12.4% over 25.4);
- Almost all of the double counting in China's processing exports comes from imported foreign contents (56.6% over 56.9);
- Highlight U.S. export producers and Chinese processing exporters' respective positions at the head and tail of the global production chain.
- Based on gross trade data, China’s RCA index is greater than 1, when domestic value-added data is used, China’s RCA index is less than 1, the same sector becomes a comparative disadvantage sector!

- The RCA ranking of United States, many EU member countries and Korea all move up.
Gross and Domestic Value-added-adjusted Revealed Comparative Advantage Indicators

- China ranking the first and the sixth based on gross trade data depend on whether considering processing trade; using domestic value-added data, China’s ranking drop to the 19th and 17th place!

- The ranking of US moved from the 26th to the 16th, also switches from being labeled as a comparative disadvantage sector to a comparative advantage sector!

- France, UK, Korea and Hungry show a similar pattern as the US, many other developed countries, such as Italy, Germany and Spain are also moving up their ranking significantly.
Conclusion

• We proposed a useful trade accounting framework. Similar to the growth accounting method, I am not expecting every economist will agree to the interpretation we made. However, the established mathematical relationship between a country's gross exports and its various value-added components is independent of how one make such interpretations;

• The established formal relationship between value-added trade and official trade statistics may provide a feasible way for international statistical agencies to report value-added trade statistics regularly in a relatively low cost fashion.

• We hope this accounting framework could be widely used in analytical and policy work together with both gross and value-added trade data.
Two Indexes Constructed from the Framework

• By using the decomposition results at the country-sector level, we can construct an index that helps us to gauge whether a country is likely to be in the upstream or downstream of the global value chain (GVC) in any particular sector.

\[
GVC_{\text{Position}}_{ir} = \ln\left(1 + \frac{VS1_{ir}}{E_{ir}}\right) - \ln\left(1 + \frac{VS_{ir}}{E_{ir}}\right)
\]

• We can also construct a separate index that helps us to gauge the extent to which a country-sector is involved in the global production chain.

\[
GVC_{\text{Participation}}_{ir} = \frac{VS1_{ir}}{E_{ir}} + \frac{VS_{ir}}{E_{ir}}
\]
Individual Country’s Position in GVCs
VS1/VS Ratios (2004)
East Asia pays a price for its long chains and relatively high tariffs.

Advanced economies have low foreign content and, hence, low costs.

Developing countries have large magnification ratio due to higher share of imported content in their manufacturing exports.
Effective tariff rate of multi-stage production

- Advanced economies have higher domestic content in their exports, hence their exporters face lower effective tariff rate

- Exporters in developing countries face higher effective tariff rate due to lower share of domestic content in their manufacturing exports

- Deep tariff cut in manufacturing sectors will benefit emerging economies more