Gross Trade Accounting, Cross Country Production Sharing and Global Value-Chain

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Presentation Outline

• Overview of existing concepts and methods in trade in value-added and vertical specialization literature and their shortcomings
  ➢ Decomposition of value-added production (forward linkage)
  ➢ Decomposition of final demand (backward linkage)
  ➢ Decomposition of gross trade flows (beyond Leontief insight)

• Use two and three country cases to illustrate the core ideas of gross trade accounting method and derivation of the decomposition formula
  ➢ Gross exports = exports of value added + domestic value added that returns home + foreign value added + double counting due to trade in intermediate goods

• Why we think the new accounting framework can reshape our understanding of global trade
Motivation

- Standard/official trade statistics are misleading in the presence of trade in intermediate goods;
- Need a framework to bridge the gap between official trade data (in gross terms) and national accounts statistics (in value added terms);
- Need a method to fully account intermediate trade. Quantifying double counting at sector and bilateral levels and investigate the source and structure of the double counting and their implications for cross country production sharing and a country’s position and participation in global value-chains (GVCs);
- Need a unified framework that nests measures of vertical specialization, trade in value-added and other IO based decomposition methods in the literature as special cases;
- Need a transparent framework helps policymakers and the public to discover GVC-related information masked by official trade data.
Measuring Domestic and Foreign Content in Exports: Original HIY measure of vertical specialization

- **A country can participate in vertical specialization in two ways**
  - Two measures of “vertical specialization”
    - uses imported intermediate inputs to produce exports; VS measures the value of imported contents embodied in a country’s exports
    - exports intermediate goods that are used as inputs by another country to produce goods for exports; VS1 measures intermediate exports sent indirectly through other countries
  
- **Two key assumptions by standard HIY measure:**
  - the intensity in the use of imported inputs is the same for goods produced for exports and for domestic sales.
    - Not true for processing trade in a large number of developing countries.
  - all imported intermediate inputs are 100% foreign sourced
    - Underestimate domestic value-added share in exports, particularly for developed countries since their imports often embodied a large share of its own value-added.
Newer Measures of Trade in Value-added

• Value-added exports and VAX Ratio
Value-added produced in source country but absorbed in destination country. Johnson and Noguera (2012) suggest use value-added exports to gross exports ratio as summary measure of value-added content of trade and index of double counting in trade statistics;

• Two major shortcomings of VAX ratio
  ➢ It is not well-behaved at the sector, bilateral, or bilateral sector level. There is no guarantee that the value added exports are less than gross exports at these disaggregated levels.
  ➢ Even when the VAX ratio is properly redefined, it still can not capture some of the important features of international production sharing.
Two Major Limitations of VAX ratio

• The key to understanding the first shortcoming of VAX ratio is a distinction between a forward-linkage-based measure of value-added exports (VAX_F), and a backward-linkage-based measure of value-added exports (VAX_B) at sector level.

• The key to understand the second shortcoming is that the structure of value-added exports and double counting besides their total sums contain important information of cross country production sharing. Two countries can have identical value added to gross exports ratios but very different structure of value added exports and double counting due to their different role in GVCs.
Two type value-added trade at sector level

- example

- In the electronic sector, forward linkage based measures would include the value added created by production factors employed at the electronics sector and incorporated into gross exports of electronics itself (direct domestic value-added exports), as well as exports of computers, consumer appliances, and automobiles (indirect domestic value-added exports), but exclude value-added contribution from any other sectors.

- In comparison, a backward linkage based measure of value-added embodied in electronic exports, would include value added in intermediate inputs from all other sectors/countries (such as glass from country A, rubber from country B, transportation and design from the home country) used to produce gross electronics exports, but exclude value-added contribution from the source country’s electronic sector to its gross exports of other sectors.
Why VAX ratio is not well behaved at sector and bilateral level?

• Direct value-added exports at the sector level are the same for both value-added export measures, but indirect value-added exports at the sector level are often very different between these two measures.

• Indirect value-added exports in the forward-linkage-based measure are the sector’s value-added embodied in other sectors’ gross exports, which has no relation to the gross exports from that sector. Therefore, VAX ratio at the sector level is not meaningful, since its denominator (sector gross exports) does not include the indirect value-added exports to other sectors. It is common in the data for some sectors with very little or no gross exports, but their products are used by other domestic industries as intermediate inputs, and thus they can have a large amount of indirect value-added exports through other sectors. In such cases, the VAX ratio will become very large or infinite. Similarly, at the bilateral level, due to indirect value-added trade via third countries, two countries can have a large volume of value-added trade even they have little or no gross trade.
Why VAX ratio miss important information of cross country production sharing?

• A country’s exports of value-added is smaller than its gross exports due to:
  
  a) the use of imported inputs to produce exports;
  
  b) a part of its DVA in exports may return home after being processed abroad;
  
  c) Double counting due to two way intermediate goods trade.

• Two countries can have similar value added to gross exports ratios but very different structure of (a), (b) and (c) due to each country’s different position and participation in GVCs.

• Examples
Shortcomings of Existing Measures

- Measures of trade in value-added and measures of vertical specialization are not equal to each other but are often used interchangeably in the literature.
- Existing measures all proposed as stand-alone indicators. No common framework that provides a unified way to account and illustrate their relationships.
- All measures proposed so far cannot identify all components in gross exports. Many studies ignore double counted components by only focusing on trade in value-added.
- To understand shortcomings of TiVA measures in existing literature better, we need to understand Leontief insights and its limitations.
What is Leontief insights

All the estimation methods used in recent efforts to measure trade in value-added are rooted in Leontief (1936).

- When $1 export is produced, a first round of value-added is generated: Direct domestic value-added induced by the $1 exports.
- To produce that export, intermediate inputs have to be used. The production of these intermediate inputs also generates value-added. This is the indirect domestic value added induced by the $1 exports.
- Such a process to generate indirect value-added can be traced throughout the economy, as intermediate inputs are used to produce other intermediate inputs.
- The total domestic value-added induced by the $1 exports is equal to the sum of direct and all indirect domestic value-added generated from the $1 exports production process.

\[ DV = V + VA + VAA + VAAA + \ldots \]

\[ = V(I + A + A^2 + A^3 + \ldots) = V(I - A)^{-1} = VB \]
Direct Domestic Value added Coefficient

\[ V^s = u[I - A^{ss} - A^{rs}] \]

\[ v_j^c = \frac{v_{a_j}}{x_j^c} = 1 - \sum_{i}^{N} a_{ij}^{sc} - \sum_{i}^{N} a_{ij}^{rc} \quad (c = s, r \quad j = 1, 2, ..., N) \]

Define \( \hat{V} \) as a 2N by 2N diagonal matrix with each country’s direct value-added coefficients by sector along the diagonal;

Define \( \hat{Y} \) as 2N by 2N final demand matrix with each country’s total final demand by sector along the diagonal;
Decomposition of value-added and final goods production based on Leontief insights (1)

When N=2

$$\hat{V}BY = \begin{bmatrix} v_1^s & 0 & 0 & 0 \\ 0 & v_2^s & 0 & 0 \\ 0 & 0 & v_1^r & 0 \\ 0 & 0 & 0 & v_2^r \end{bmatrix} \begin{bmatrix} b_{11}^{ss} & b_{12}^{ss} & b_{11}^{sr} & b_{12}^{sr} \\ b_{21}^{ss} & b_{22}^{ss} & b_{21}^{sr} & b_{22}^{sr} \\ b_{11}^{rs} & b_{12}^{rs} & b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rs} & b_{22}^{rs} & b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^s & 0 & 0 & 0 \\ 0 & y_2^s & 0 & 0 \\ 0 & 0 & y_1^r & 0 \\ 0 & 0 & 0 & y_2^r \end{bmatrix}$$

Decompose GDP by sector; forward linkage based

Decompose final goods by VA source; backward Linkage based
Decomposition of value-added and final goods production based on Leontief insights (2)

- Sum up the matrix along the row, accounts how each country's domestic value-added originated in a particular sector is used by the sector and all its down stream countries/sectors.

- Sum up the matrix along the columns, gives the country/sector sources of value-added in each country's final demand, accounts all upstream countries/sectors’ value-added contribution to a specific country/sector’s final goods output.

- Thus, supply side perspective (sum across columns) decomposes how each country's GDP by industry are used, directly or indirectly to satisfy domestic or foreign final demand, while the user side perspective (sum across rows), decomposes a country/sector's final goods and services into its original country/sector sources.
Applications of Leontief insights in trade in value-added and GVC decomposition literature

- Decompose final goods to its country/sector value-added sources based on Leontief insights (backward linkage, sum matrix $\hat{Y}B\hat{Y}$ across rows).
  - **GVC income**: Value-added countries contribute to the production of final manufacturing goods (Timmer et al, 2013);
  - Share of foreign value-added in total value of final products (Los, Timmer, and Vries, 2014)

- Decompose GDP by industry to where and how it is used based on Leontief insights (forward looking linkage, sum matrix $\hat{Y}B\hat{Y}$ across columns).
  - Johnson and Noguera (2012) only measured sector value-added absorbed by foreign countries, part of GDP by industry statistics.
Limitation of Leontief insight

- Estimating value-added exports can be accomplished by directly applying the original Leontief insight. It does not require the decomposition of intermediate trade flows. However, discovering the structure of cross country production sharing and GVC related information from trade statistics requires finding a way to decompose intermediate trade into value-added and double-counted parts, which cannot be achieved by simply applying Leontief’s insight;

- Because gross intermediate trade flows have to be solved first from the inter-country input-output (ICIO) models for any given level of final demand. In Wang et al. (2013), we find a way to solve this endogeneity issue by categorising all bilateral intermediate trade flows into major final demand groups according to their final destination of absorption. This key technical step converts gross outputs (and gross exports) – usually endogenous variables in standard ICIO models – to exogenous variables in the gross trade accounting framework we proposed.
Decompose Gross Exports
based on but beyond Leontief insights

\[ E^{sr} = Y^{sr} + A^{sr} X^r \]  (1)

\[ Y^{sr} = V^s B^{ss} Y^{sr} + V^r B^{rs} Y^{sr} \]  (2)

The key is decompose \( A^{sr} X^r \)

\[ X^r = \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} = \begin{bmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{bmatrix} \begin{bmatrix} y_1^{ss} + y_1^{sr} \\ y_2^{ss} + y_2^{sr} \end{bmatrix} + \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rr} + y_1^{rs} \\ y_2^{rr} + y_2^{rs} \end{bmatrix} \]  (3)

\[ A^{sr} X^r = \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} x_1^r \\ x_2^r \end{bmatrix} = \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{bmatrix} \begin{bmatrix} y_1^{ss} + y_1^{sr} \\ y_2^{ss} + y_2^{sr} \end{bmatrix} + \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} b_{11}^{rr} & b_{12}^{rr} \\ b_{21}^{rr} & b_{22}^{rr} \end{bmatrix} \begin{bmatrix} y_1^{rr} + y_1^{rs} \\ y_2^{rr} + y_2^{rs} \end{bmatrix} + \begin{bmatrix} a_{11}^{sr} & a_{12}^{sr} \\ a_{21}^{sr} & a_{22}^{sr} \end{bmatrix} \begin{bmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{bmatrix} \begin{bmatrix} y_1^{sr} \\ y_2^{sr} \end{bmatrix} \]  (4)
Gross bilateral intermediate trade between Country s and r

Exporting Country S

Intermediate exports

Direct Importing Country R

Third Country T

Final Goods consumed in S

Final Goods consumed in R

Final Goods consumed in T

Intermediate trade flows

Domestic final good flows

Final trade flows
Gross Exports Accounting

Building on the decomposition of gross bilateral intermediate trade according to their final destination of absorption, we decompose gross trade flows at any level of disaggregation into 16 value-added and double-counted components. **Conceptually, these 16 components can be grouped into four buckets:**

- **Domestic value-added absorbed abroad (DVA);**
- **Domestic value added that is initially exported but finally returned and consumed home via imports from other countries (RDV);**
  
  It is not part of a country's exports of value-added, but account for part of the country's GDP;
- **Foreign value added used in the production exports (FVA);**
- **Double counted terms due to intermediate goods being traded back and forth that cross border multiple times (PDC).**

These intermediate trade transactions are not part of any country’s GDP or final demand, similar to domestic inter-industry transactions that use one type of intermediate input to produce another. Since all cross-country trade transactions are recorded by each country’s customs, they show up in the official trade statistics. Make them different from domestic intermediate input transactions, which are deducted from total gross output when official GDP by industry statistics are calculated.
Gross Trade Accounting: Concepts

(0) Gross exports (goods and services) (E)

(1) Final goods and services exports (DVA_FIN)
(2) Intermediates exports absorbed by direct importer (DVA_INT)
(3) Intermediates sent to first importer and then re-exported to third country (DVA_INT_REX)
(4) Domestic value-added first exported then returned home (RDV)
(5) Pure double counting from domestic sources (DDC)
(6) Foreign value added contained in final exports (FVA_FIN)
(7) Foreign value added contained in intermediates exports (FVA_INT)
(8) Pure double counting from foreign sources (FDC)

Domestic Content (DC, sum (1) through (5))
Vertical Specialization (VS)

E can be at country/sector, country aggregate, bilateral /sector or bilateral aggregate; both DVA and RDV are based on backward linkages
Major Analytical Results Regarding to Summary Measure of Factor Content of Trade and Double Counting

- In a world of three or more countries, domestic value-added in exports that is absorbed abroad (DVA), forward-linkage-based value-added exports (VAX_F), and backward-linkage-based value-added exports (VAX_B), are, in general, not equal to each other at the bilateral/sector level. These value-added trade measures are only equal at the country aggregate level. VAX_F and VAX_B are equal at the bilateral aggregate level, while DVA and VAX_B are the same at the country/sector level.

- DVA at the sector level is always less than or equal to the sector-level gross bilateral exports. Therefore, the ratio of domestic value-added absorbed abroad to gross exports has an upper bound of one at any level of disaggregation as long as gross exports are positive.

- VAX_B at the sector level is always less than or equal to the country’s sector-level gross exports. Therefore, the ratio of VAX_B to gross exports has an upper bound of one at the country/sector level when gross exports are positive.

- VAX_F is always less than or equal to sector-level value-added production. Therefore, the ratio of VAX_F to GDP by sector has an upper bound of one.
### US-China trade in Electrical and Optical Equipment (WIOD C14)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total gross exports</th>
<th>DVA_Fin</th>
<th>DVA_INT</th>
<th>DVA_Intrex</th>
<th>RDV</th>
<th>FVA from partner</th>
<th>FVA from third countries</th>
<th>PDC</th>
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<tbody>
<tr>
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<td></td>
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<tr>
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**China exports to the United States**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total gross exports</th>
<th>DVA_Fin</th>
<th>DVA_INT</th>
<th>DVA_Intrex</th>
<th>RDV</th>
<th>FVA from partner</th>
<th>FVA from third countries</th>
<th>PDC</th>
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<td>718</td>
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**US exports to China**

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<th>Year</th>
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<th>DVA_INT</th>
<th>DVA_Intrex</th>
<th>RDV</th>
<th>FVA from partner</th>
<th>FVA from third countries</th>
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**Trade Balance**
## US-China trade in Electrical and Optical Equipment (WIOD C14)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Exp</th>
<th>DVA</th>
<th>DVA_Fin</th>
<th>DVA_INT</th>
<th>DVA_Intrex</th>
<th>RDV</th>
<th>FVA_partner</th>
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<th>PDC</th>
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<td>China exports to the United States</td>
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<tr>
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<td>2.0</td>
<td>5.8</td>
<td>4.3</td>
<td>67.8</td>
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Decomposing DVA in Exports
- Textile and Products (WIOD sector 04)
Decomposing DVA in exports
- Electrical and optical equipment (WIOD sector14)
### Average VS Structure of World Manufacturing Industries, 1995-2001

<table>
<thead>
<tr>
<th>Year</th>
<th>VS share in gross exports</th>
<th>% of VS</th>
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<tr>
<td></td>
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<td>FVA _FIN</td>
<td>FVA _INT</td>
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<tr>
<td>1995</td>
<td>22.5</td>
<td>45.5</td>
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<tr>
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<tr>
<td>2011</td>
<td>30.8</td>
<td>40.6</td>
<td>34.5</td>
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VS Structure of Electric and Optical Equipment
Exports for selected Asian Economies

China

Indonesia

Chinese Taipei

India
RCA Index should take into account both domestic and international production sharing

- Traditional RCA ignores two important facts:
  - A country-sector’s gross exports include foreign value-added and double counted terms due to back and forth intermediate goods trade.
  - A country-sector’s value added may be exported indirectly via the country’s exports in other sectors.
- A conceptually correct measure of comparative advantage needs to exclude foreign-originated value added and pure double counted terms but include indirect exports of a sector’s value added through other sectors of the exporting country.
RCA indexes for electric and optical equipment exports

China

USA

RCA_ Gross  RCA_Value Added

RCA_ Gross  RCA_Value Added
RCA indexes for business services exports

Germany

India

RCA_Gross  RCA_Value Added

RCA_Gross  RCA_Value Added
Conclusion

- Our accounting method identifies exports of domestic value added; domestic value-added exported first but returns home; foreign value-added used in production of exports; and double counted items arising from two way intermediate goods trade.

- These conceptually different components sum up to 100% of official gross exports statistics at any level of disaggregation. By identifying which parts of the official data are double counted and the sources of the double counting, we provide an effective way to correctly interpret official trade statistics in value-added terms and provide an index to quantitatively measure what and how much is double counted for each bilateral/sector trade flows.

- The structural information of domestic value-added and double counting in addition to their total sums can be used to evaluate a country/sector’s position and participation in global production chains.