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

Robert Koopman and Zhi Wang
United States International Trade Commission
Shang-Jin Wei, Columbia University, CEPR and NBER

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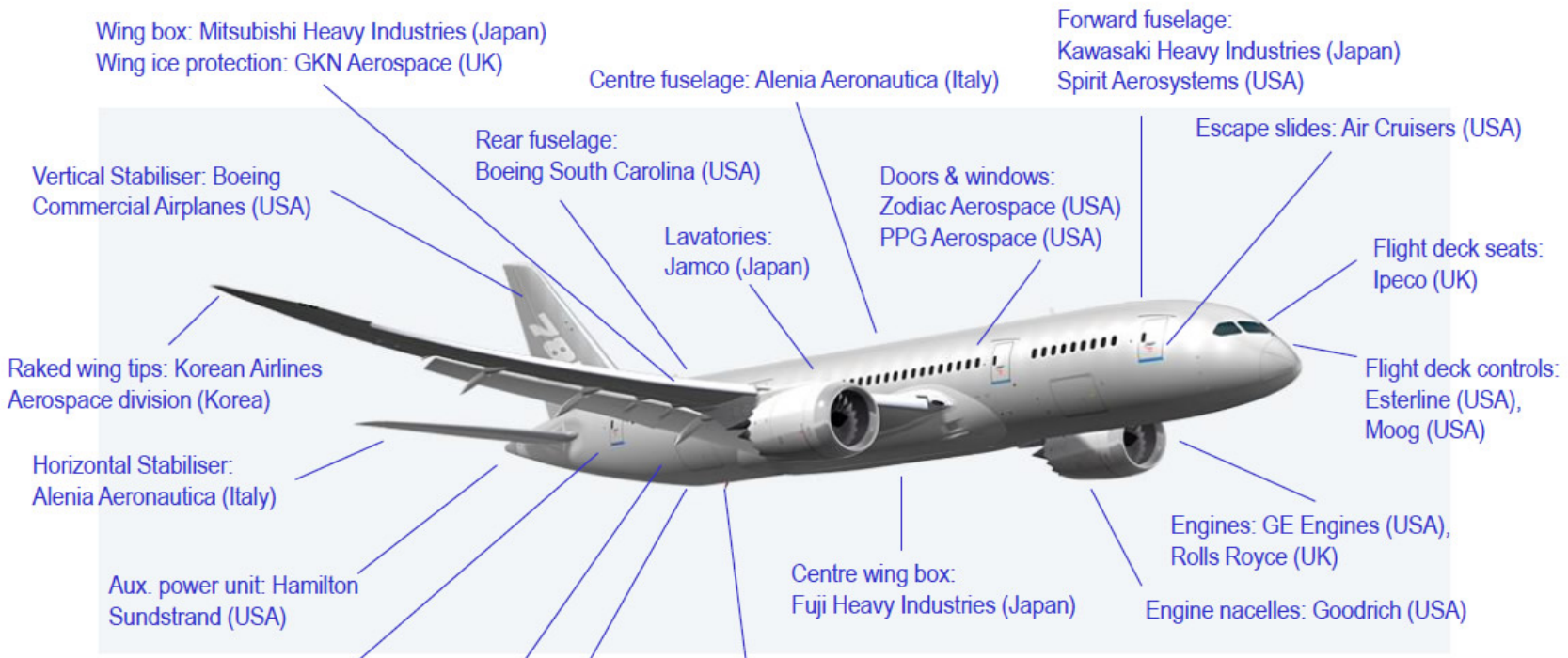
The views expressed in this presentation are solely of the presenter. It is not meant to represent in anyway the official views of the USITC and its Commissioners

Presentation Outline

- Motivation
- Conceptual Framework
  - Transparent: block matrix formulation
  - Complete: decompose a country's gross exports into five basic value-added components, establishing a full concordance between value-added measures and official trade statistics;
  - Comprehensive: integration of all existing measures in the literature
- Empirical Results
  - Highlight regional differences in supply chain participation
  - Quantitative index showing whether a sector/country is likely located in the upstream or downstream of the GVCs.
  - Report several applications of our new measures and data to illustrate their potential to reshape our understanding of global trade.
- Database improvement and Limitations
  - Why end-use classification is better than proportion assumption
  - What end-use classification can help, what it can't

Fragmentation of production: the example of the Boeing 787 Dreamliner



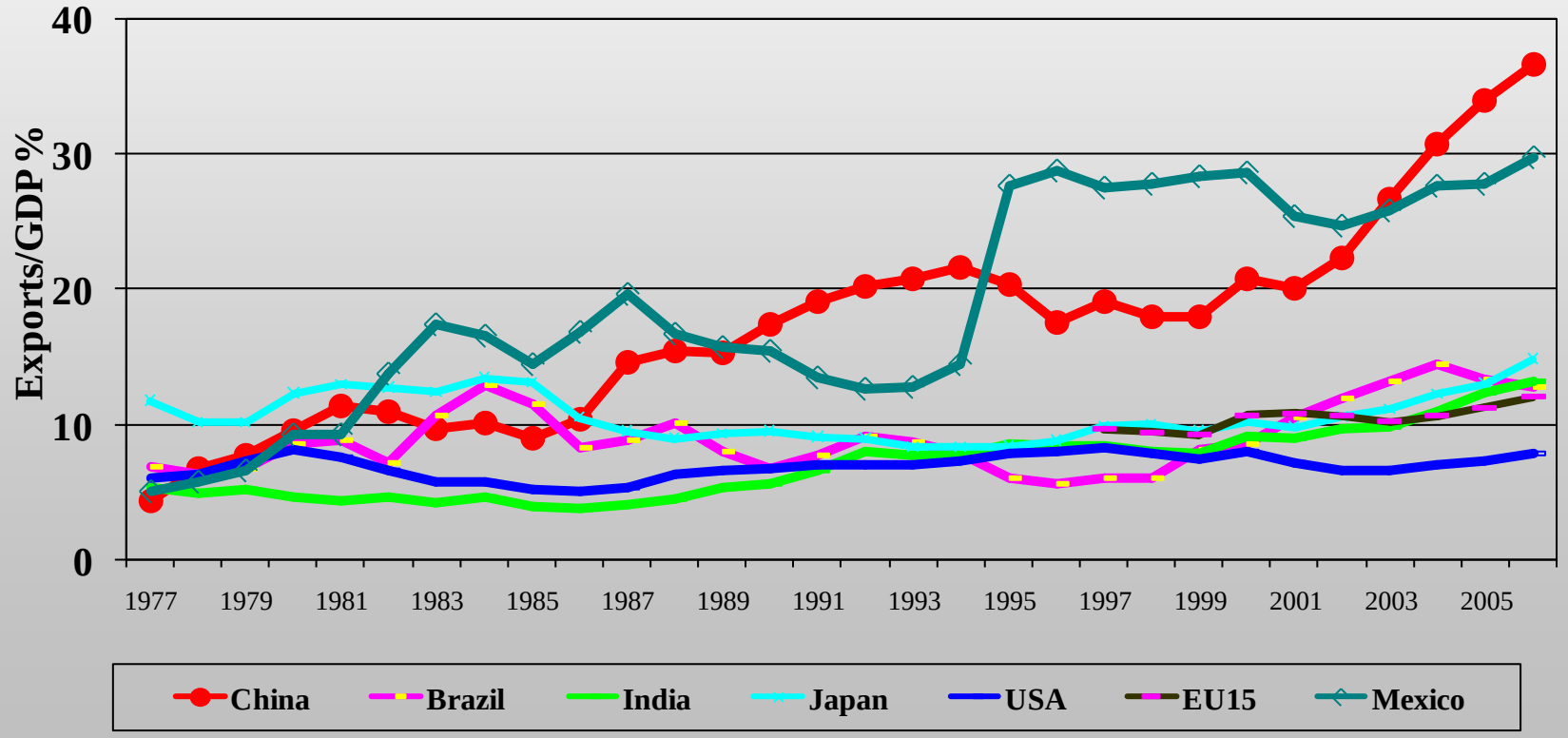
Source: www.newairplane.com

- **Story of iPod (Linden, Kraemer, and Dederick, 2007)**
- **In Bilateral trade statistics**
  - **U.S import value $150.00**
  - **China's value added $4.00**
- **In the presence of global production network, gross trade data are repeat-counted.**

It is the domestic value added that matters for GDP. Analysis based on gross trade statistics is misleading in terms of GDP's dependence to exports and exaggerates the technology sophistication of developing country's exports.

Gross Exports to GDP ratio is a misleading indicator of export dependence

Gross export/GDP for large economies in the world, 1977-2006



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 that is multiple counted, thus creating measures of trade that are consistent with the SNA standard.

- Help policy makers and the public to understand what the official trade statistics really means, to avoid misleading conclusions.

- Report an applications of our domestic content in exports measure to illustrate the potential implications of our methodology and database to reshape our understanding of global trade.

Literature in Value-Chain and Value-added Trade
from a product to a global view

- Single product:
  - iPod, HP notebook PC Dedrick, Kraemer, and Linden,2008
  - iPhone, ADB, 2011
- Single country:
  - Vertical specialization: Hummels, Ishii, Yi, 2001
  - Domestic value-added: Koopman, Wang and Wei, 2008
  - Offshoring: Feenstra and Jensen ,2009
- Regional focus:
  - WTO-JETRO (2011); Wang, Powers, and Wei (2009)
- Global :
  - Daudin, Rifflart, and Schweisguth,2009; Johnson and Noguera (2009)
  - KPWW, 2010, WIOD (2010), OECD(2011)

Related Literature and Existing Measures

- Hummels, Ishii, and Yi (2001) measures of vertical trade
  - VS and VS1
- Newer measures in value-added trade
  - VAX: Ratio of value-added exports to gross exports (Johnson and Noguera, 2010)
  - VS1*: domestic value-added in intermediates first exported then returns home (Daudin et al., 2010)
- The difference between value-added trade and domestic content in exports (Koopmam, Powers, Wang and Wei, 2011)

Measure Domestic and Foreign Content in Exports: HIY – Single country view: 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 value-added 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.

From Single Country to Global View: Production and trade in a two-country world

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

$$X_s = A_{ss} X_s + A_{sr} X_r + Y_{ss} + Y_{sr} \qquad (1)$$

  - In block matrix notations

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

  - Rearrange

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

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' final goods

From Single Country to Global View: Value added Share Matrix

- Direct domestic value added in production:

$$V_1 = u[I - A_{11} - A_{21}]$$

where

V_r: direct domestic value-added coefficient;

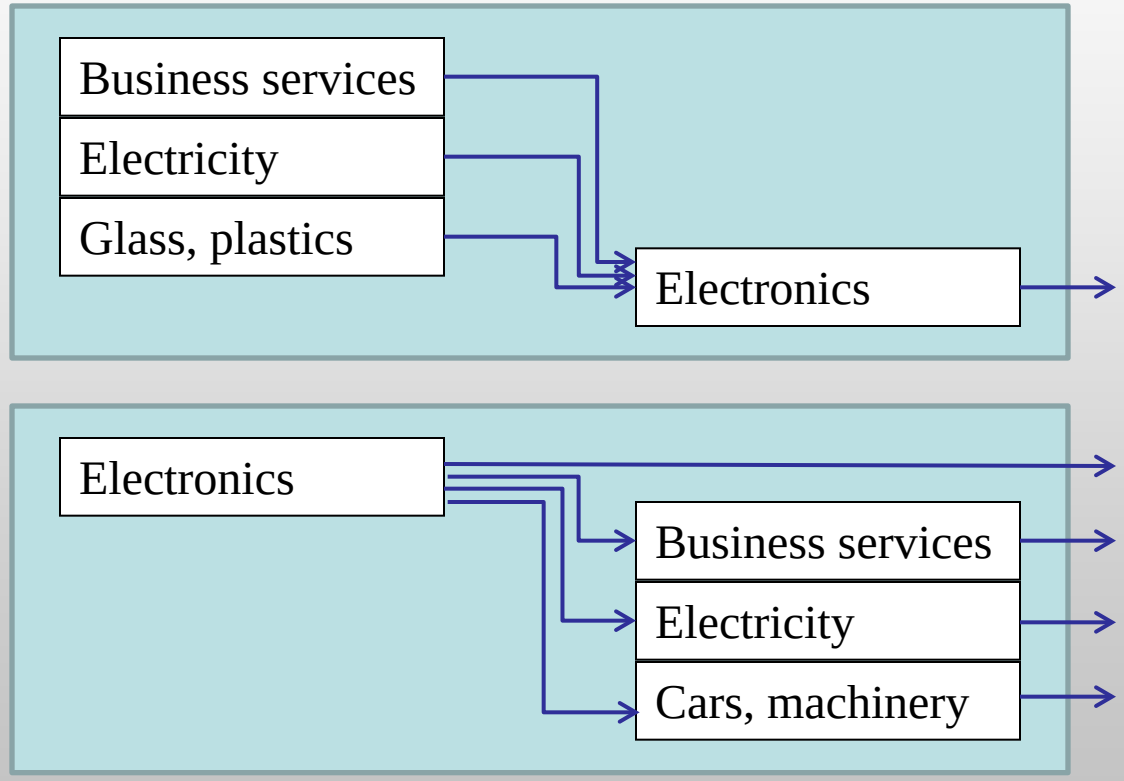
= 1 – intermediate input share from both countries

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

$$VB = \begin{bmatrix} V_1B_{11} & V_1B_{12} \\ V_2B_{21} & V_2B_{22} \end{bmatrix} \qquad V = \begin{bmatrix} V_1 & 0 \\ 0 & V_2 \end{bmatrix}$$

$$V_1B_{11} + V_2B_{21} = DVS_1 + FVS_1 = u \qquad (4)$$

Concept: Domestic contents and value-added exports by sectors



Domestic contents by sectors measures all upstream sectors' contributions to DV in a specific sector's exports

Value-added trade by sectors measures DV produced by factors employed in a specific sector and then embodied in gross exports of all downstream sectors

Gross Output Decomposition Matrix

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

$$\begin{bmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} = \begin{bmatrix} B_{11}Y_{11} + B_{12}Y_{21} & B_{11}Y_{12} + B_{12}Y_{22} \\ B_{21}Y_{11} + B_{22}Y_{21} & B_{21}Y_{12} + B_{22}Y_{22} \end{bmatrix} \quad (5)$$

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

Value-added exports in terms of all countries' final demand

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

$$\hat{V}BY = \begin{bmatrix} \hat{V}_1 & 0 \\ 0 & \hat{V}_2 \end{bmatrix} \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \qquad (6)$$

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

$$VT_{12} = V_1 X_{12} = V_1 B_{11} Y_{12} + V_1 B_{12} Y_{22} \qquad (7)$$

Concept: Domestic content and value-added exports

- Domestic/foreign content of exports is aligns well with global production chain literature.
- Value-added trade measures is more closely related to the literature on factor contents of trade.
- These 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.

Domestic content in exports and its relationship with value-added exports

- From equation (1) gross exports of country 1 are

$$E_{12} = Y_{12} + A_{12} X_2 \qquad (9)$$

- Combine equations (9) and (4)

$$E_{12} = V_1 B_{11} E_{12} + V_2 B_{21} E \qquad (10)$$

- The first term in the right hand of equation (10) equals

$$V_1 B_{11} E_{12} = V_1 B_{11} Y_{12} + V_1 B_{11} A_{12} X_2 \qquad (11)$$

- We define equation (11) as domestic content in exports and we are able to show:

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

Double counting measure

Complete Decomposition of Gross exports

- The second term in the right hand of equation (7) equals

$$V_2 B_{21} E_{12} = V_2 B_{21} Y_{12} + V_2 B_{21} A_{12} X_2 \qquad (13)$$

- Combining equations (7), (12) and (13), we get the full decomposition of country 1's gross exports

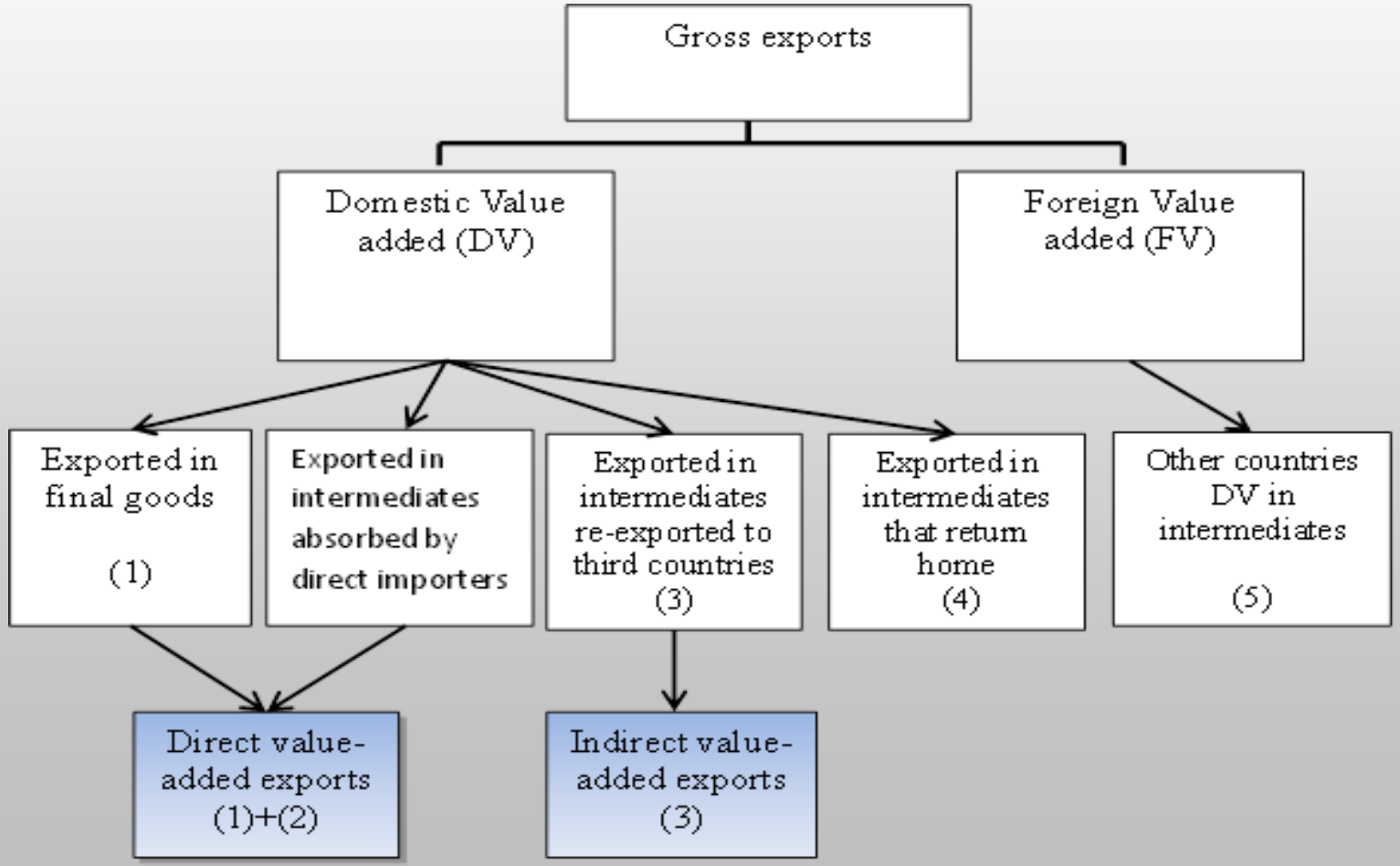
$$E_{12} = V_1 B_{11} E_{12} + V_2 B_{21} E_{12} = V_1 B_{11} Y_{12} + V_1 B_{12} Y_{22} \qquad (1) + (2)$$

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

$$+ V_2 [B_{21} Y_{12} + B_{21} A_{12} (I - A_{11})^{-1} Y_{22}] + V_2 B_{21} A_{12} [X_2 - (I - A_{22})^{-1} Y_{22}] \qquad (5)$$

- The third country term is missing in our two country case. Which is box (3) in graph in next slide

Decomposition of gross exports: concepts



Unified all existing value-added measures

- 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).

HIY VS is a special case of our FV

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

$$\text{FV} = \begin{bmatrix} V_2 B_{21} E_{1*} \\ V_1 B_{12} E_{2*} \end{bmatrix} = \begin{bmatrix} u(A_{21} - A_{12}(I - A_{22})^{-1}A_{21})(I - A_{11} - A_{12}(I - A_{22})^{-1}A_{21})^{-1}E_{1*} \\ u(A_{12} - A_{21}(I - A_{11})^{-1}A_{12})(I - A_{22} - A_{21}(I - A_{11})^{-1}A_{12})^{-1}E_{2*} \end{bmatrix}$$

$$\text{VS} = \begin{bmatrix} uA_{21}(I - A_{11})^{-1}E_{1*} \\ uA_{12}(I - A_{22})^{-1}E_{2*} \end{bmatrix}$$

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 VAS 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*)

$$\text{VAS\_E} = VBE = \begin{bmatrix} V_1B_{11}\frac{E_1}{uE_1} & V_1B_{12}\frac{E_2}{uE_2} & V_1B_{13}\frac{E_3}{uE_3} \\ V_2B_{21}\frac{E_1}{uE_1} & V_2B_{22}\frac{E_2}{uE_2} & V_2B_{23}\frac{E_3}{uE_3} \\ V_3B_{31}\frac{E_1}{uE_1} & V_3B_{32}\frac{E_2}{uE_2} & V_3B_{33}\frac{E_3}{uE_3} \end{bmatrix}$$

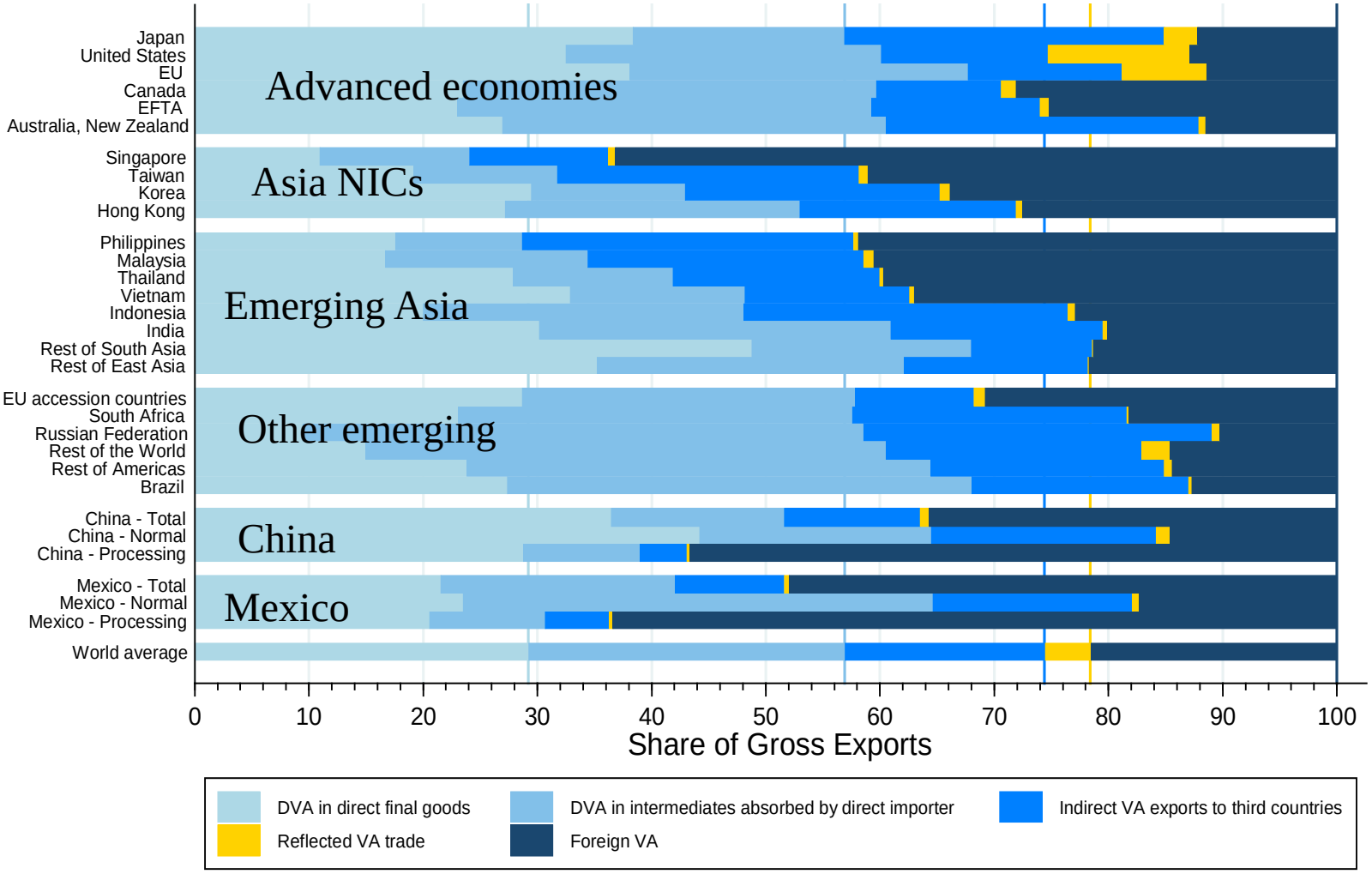
VS share: imported inputs from 2 and 3 embodied in country 1's exports

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



Key differences by region

- Japan, Australian send much of its DV exports to final suppliers indirectly through third countries;
- US uses lots of imported inputs in its exports; imported DV supplied by Canada, Mexico, and US itself;
- East Asia has the longest chains–little of its VA exports is absorbed by direct importer and use the most FV in its gross exports;
- NAFTA and EU makes Mexico and new EU member countries become outliers among non-Asian emerging economies

Applications of the new measures and database

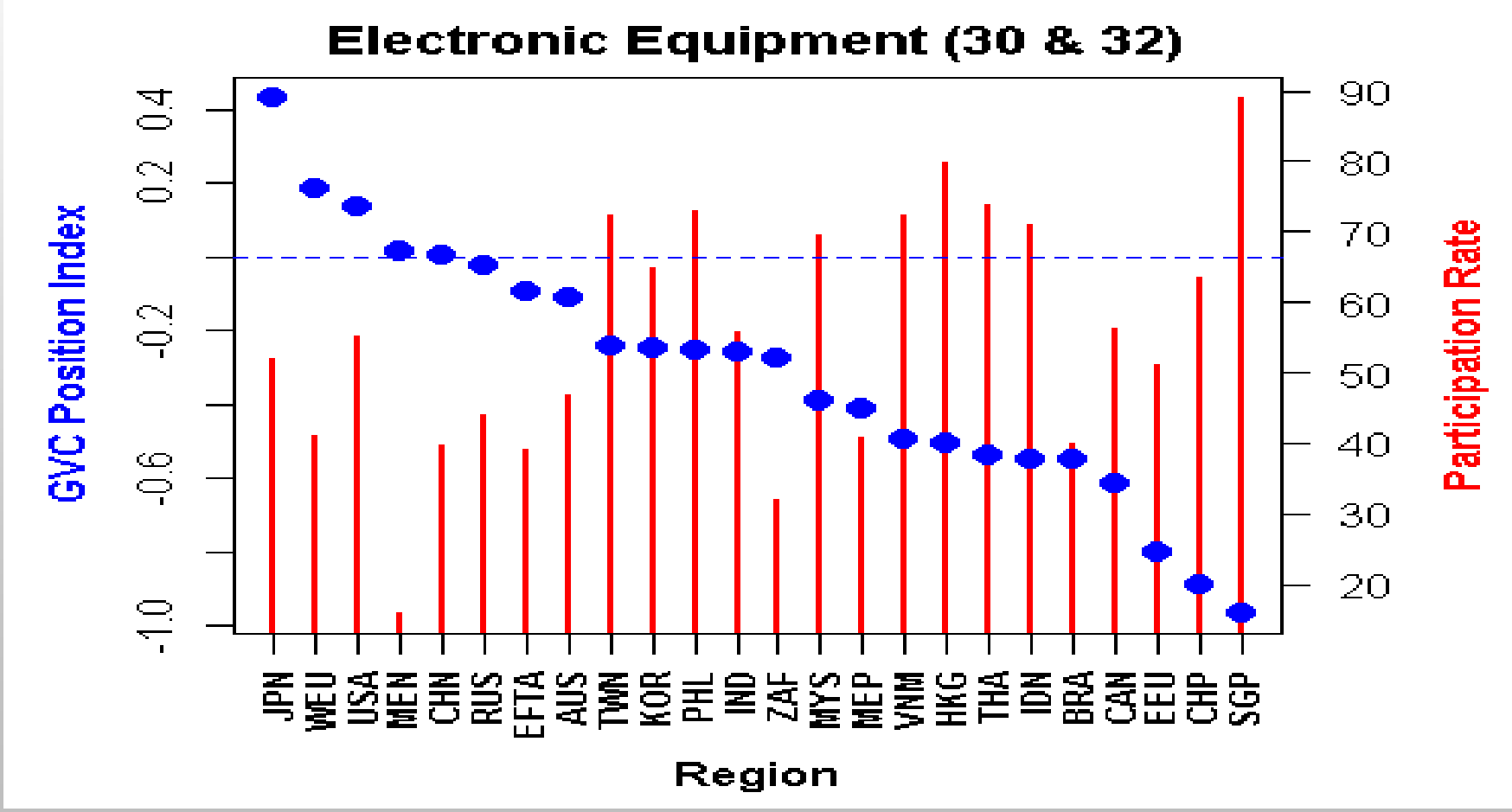
- By using the decomposition results at the country-sector level, we can construct an index that helps us to gauge whether a country is likely to be in the upstream or downstream of the global value chain (GVC) in any particular sector.

$$\text{GVC\_Position}_{ir} = Ln(1+\frac{\text{IV}_{ir}}{E_{ir}}) - Ln(1+\frac{\text{FV}_{ir}}{E_{ir}})$$

- 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.

$$\text{GVC\_Participation}_{ir} = \frac{\text{IV}_{ir}}{E_{ir}} + \frac{\text{FV}_{ir}}{E_{ir}}$$

Global Value Chains - Position and Participation Indices



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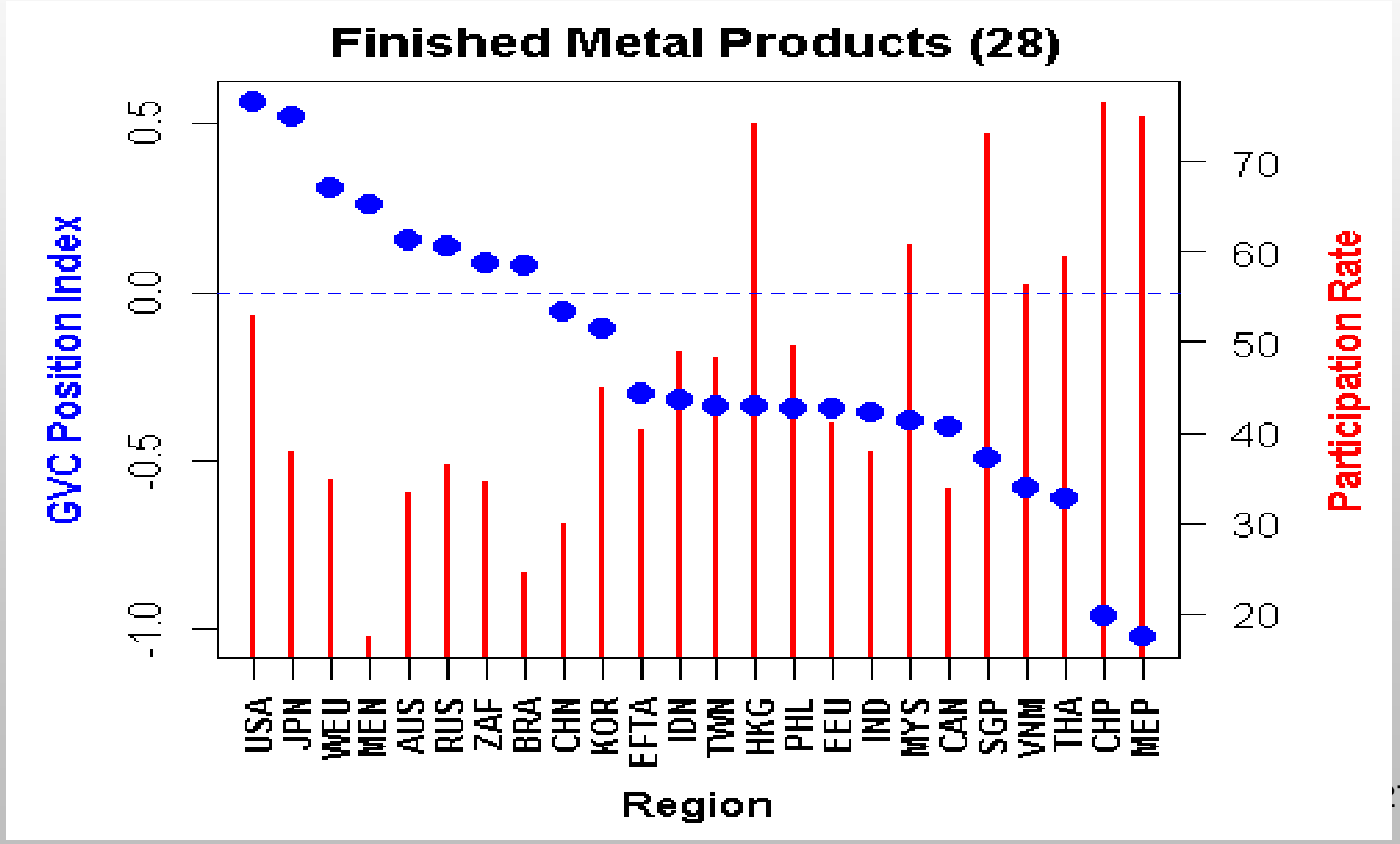

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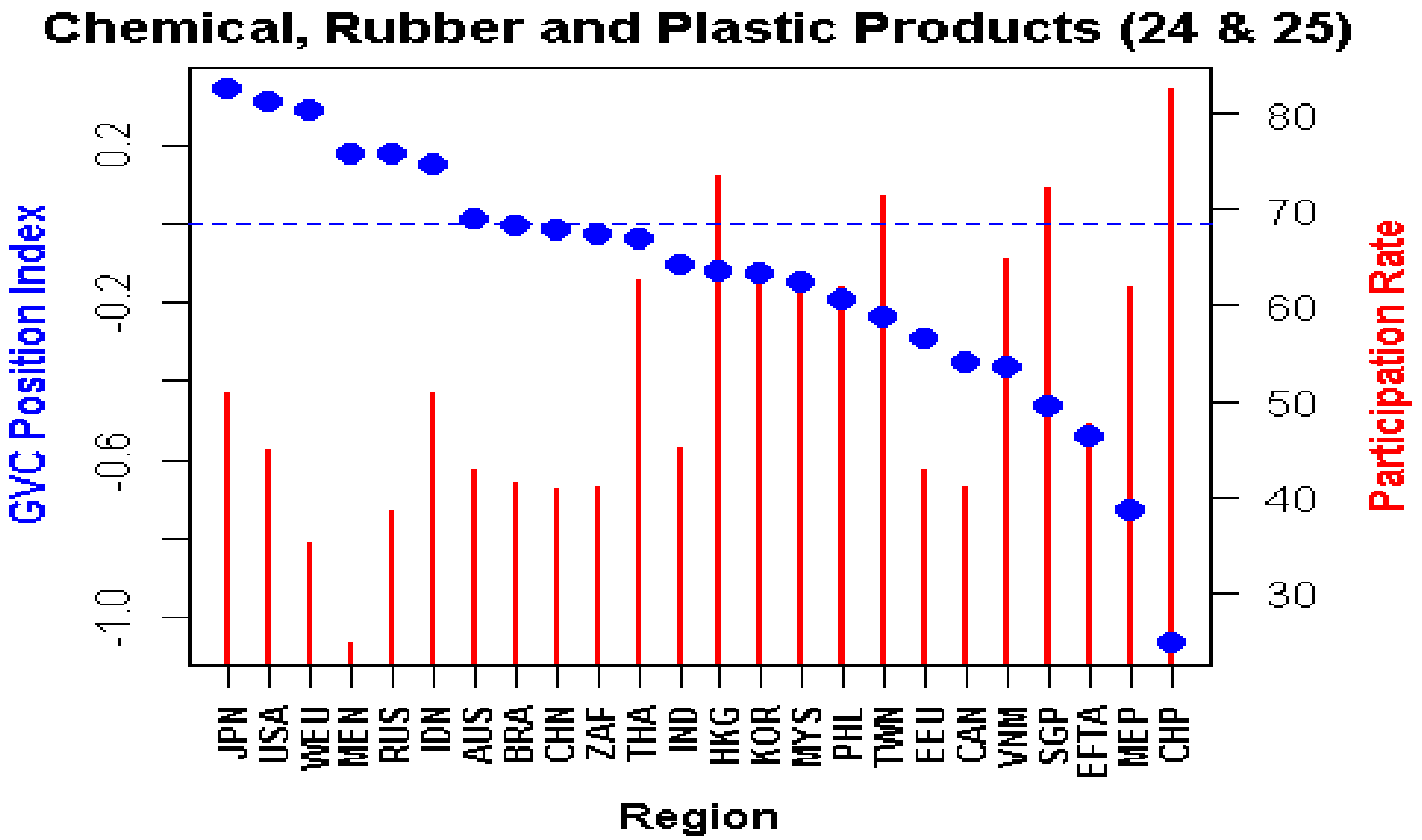

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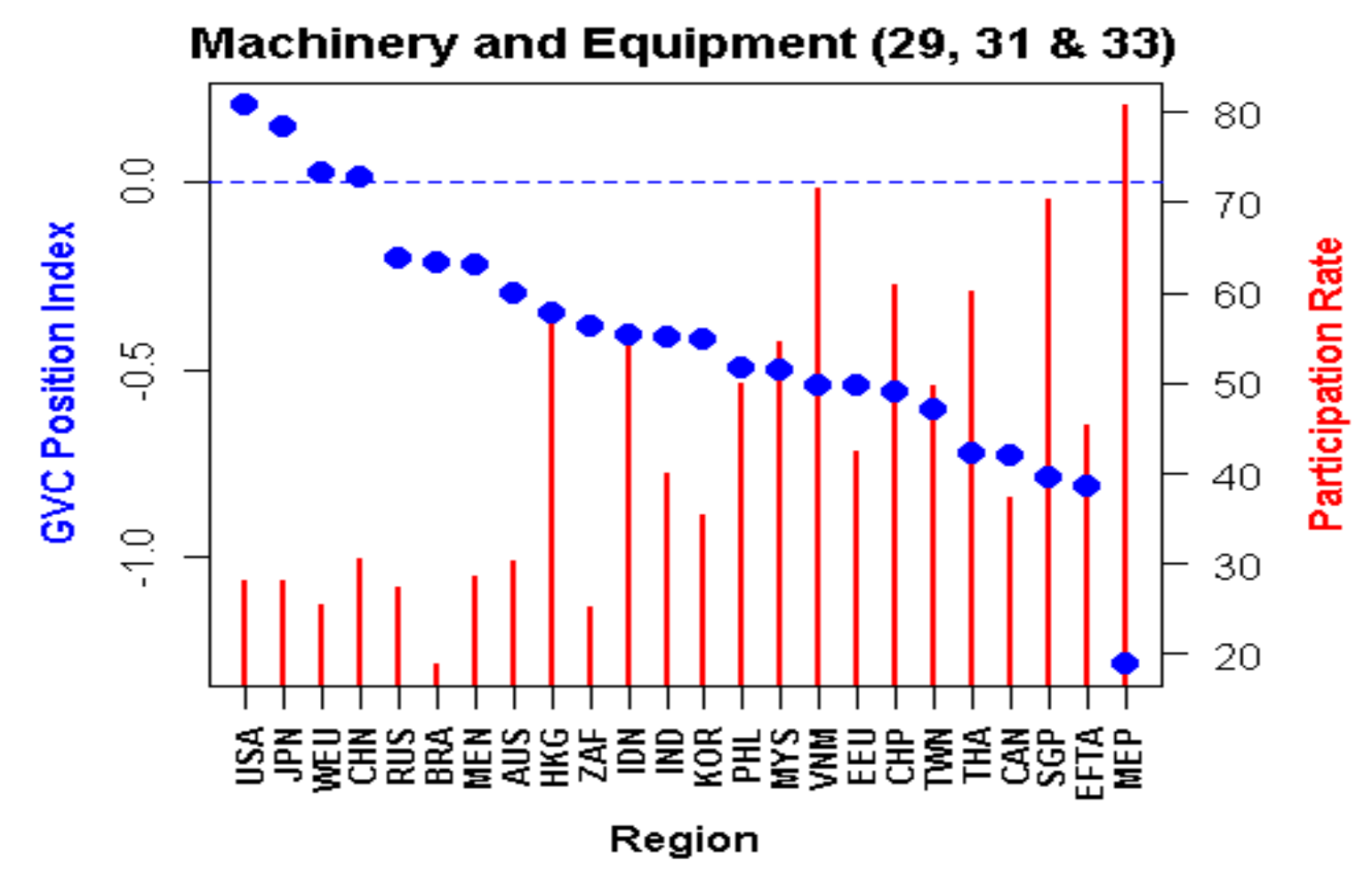

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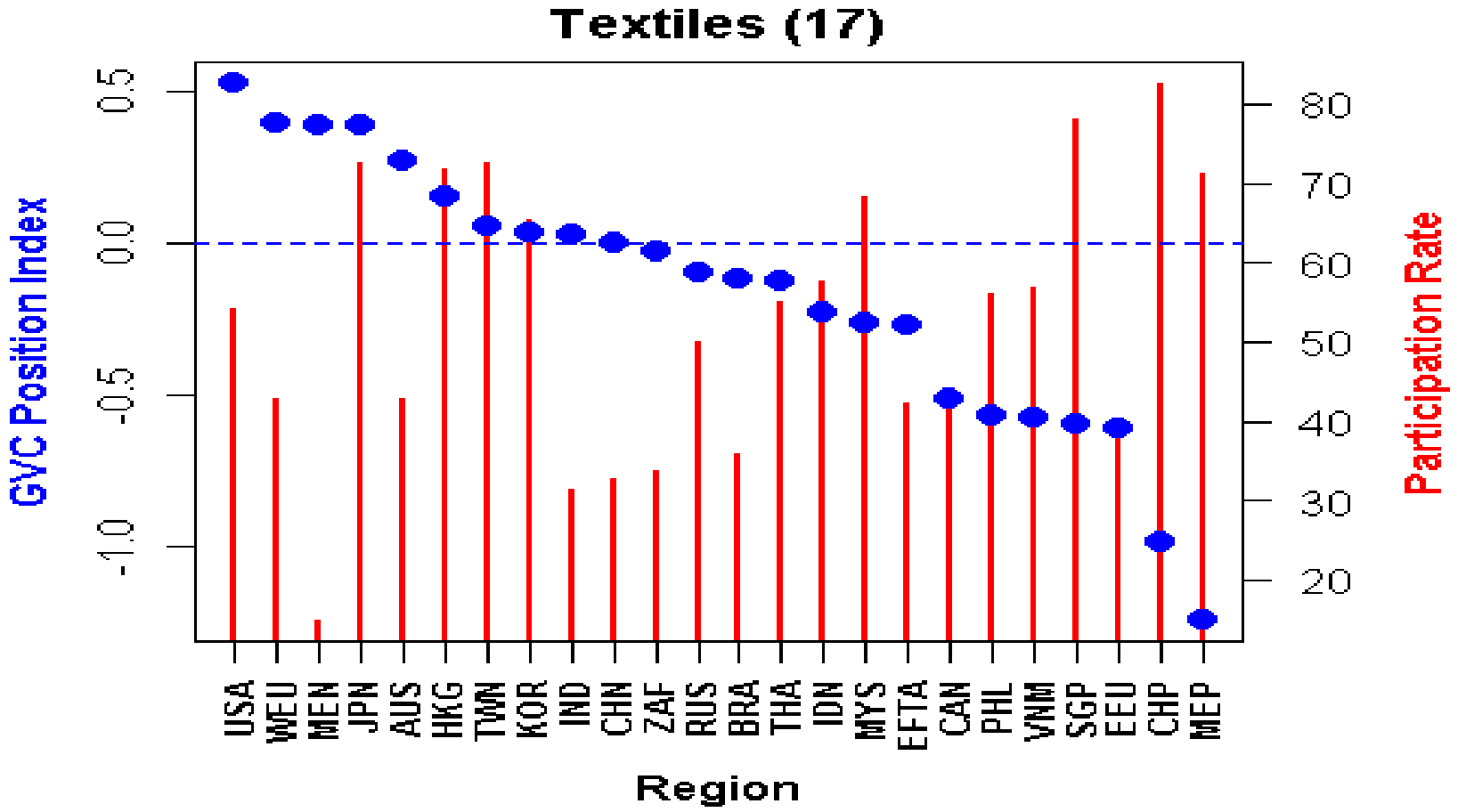

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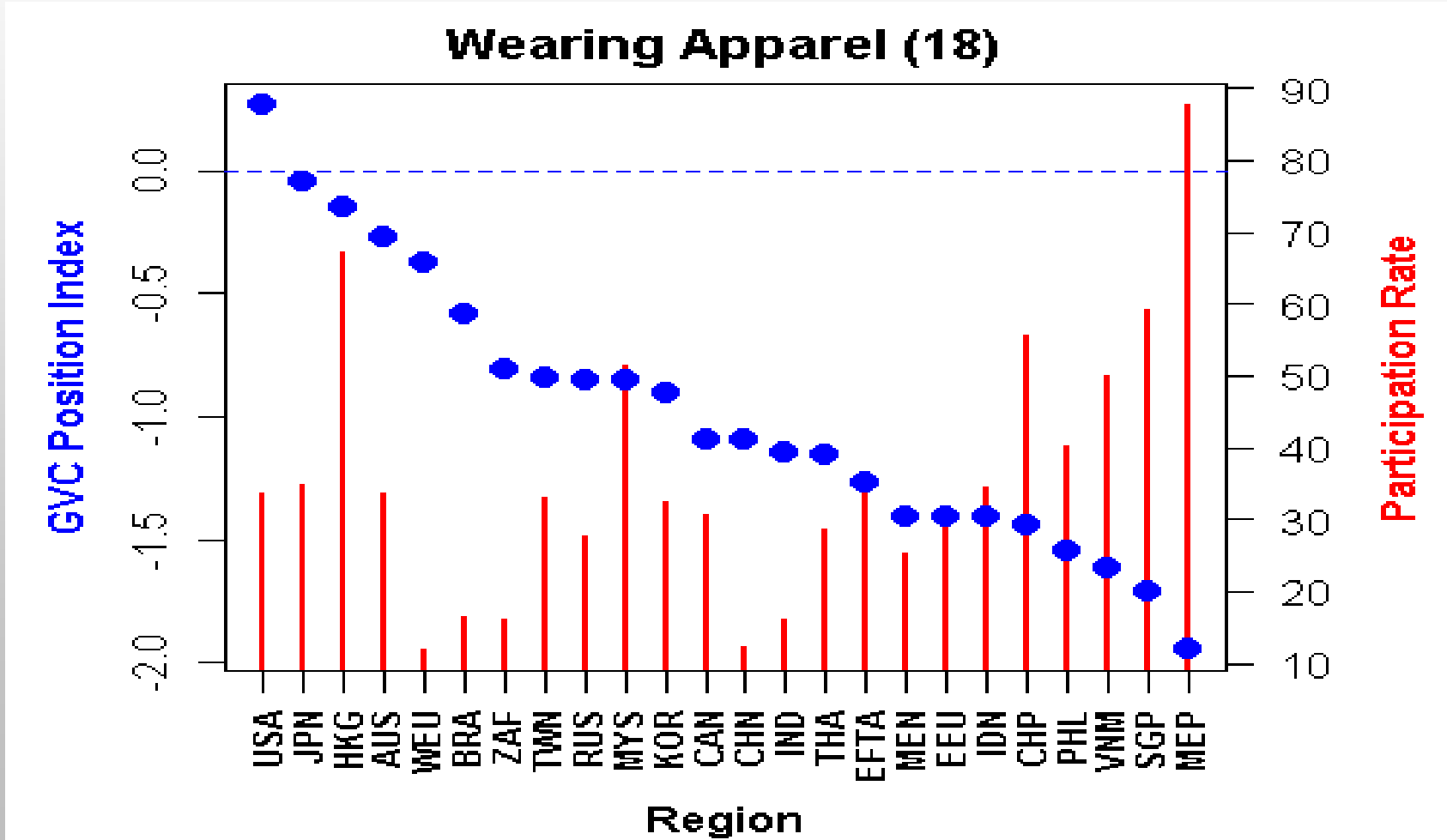
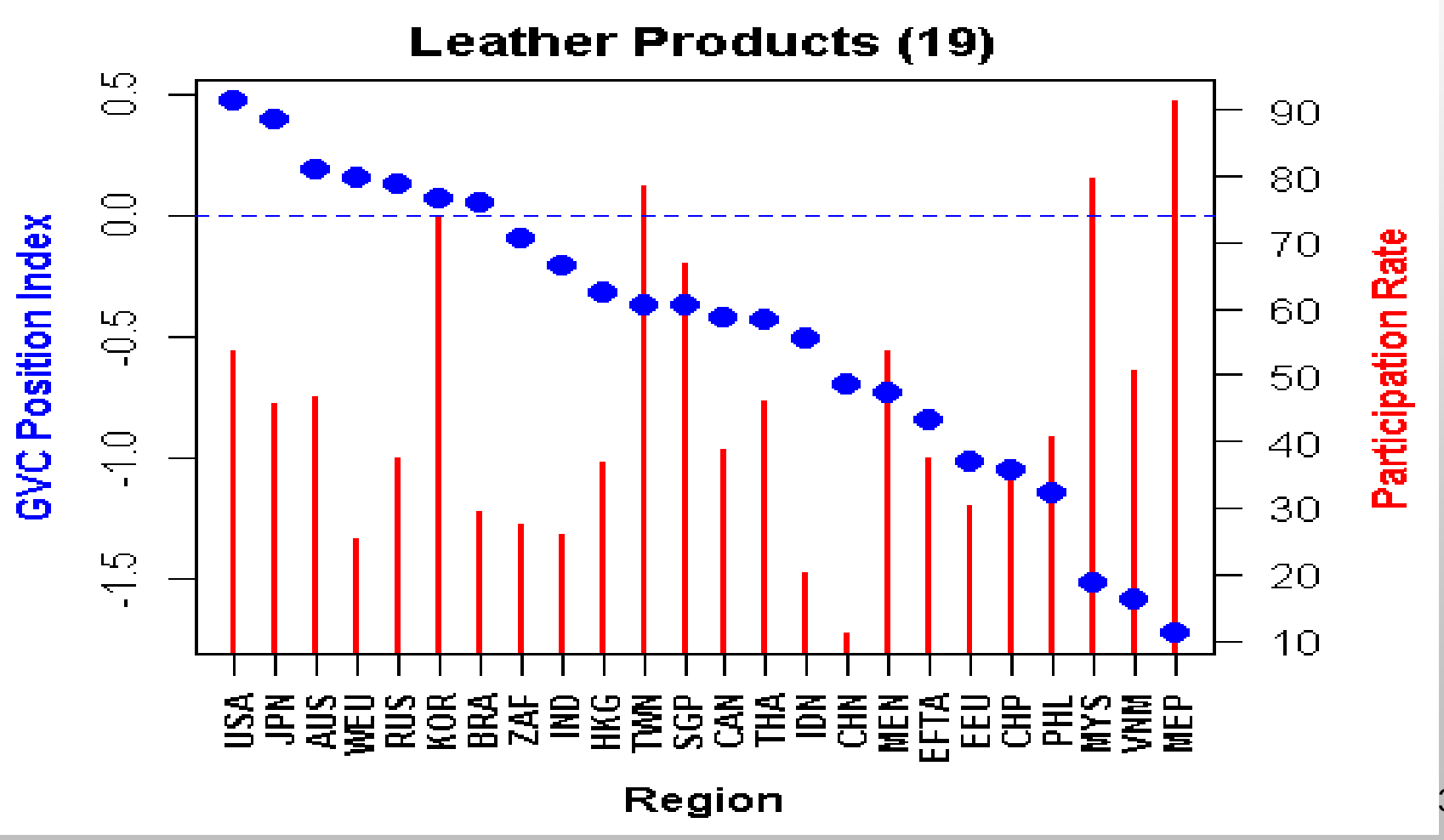
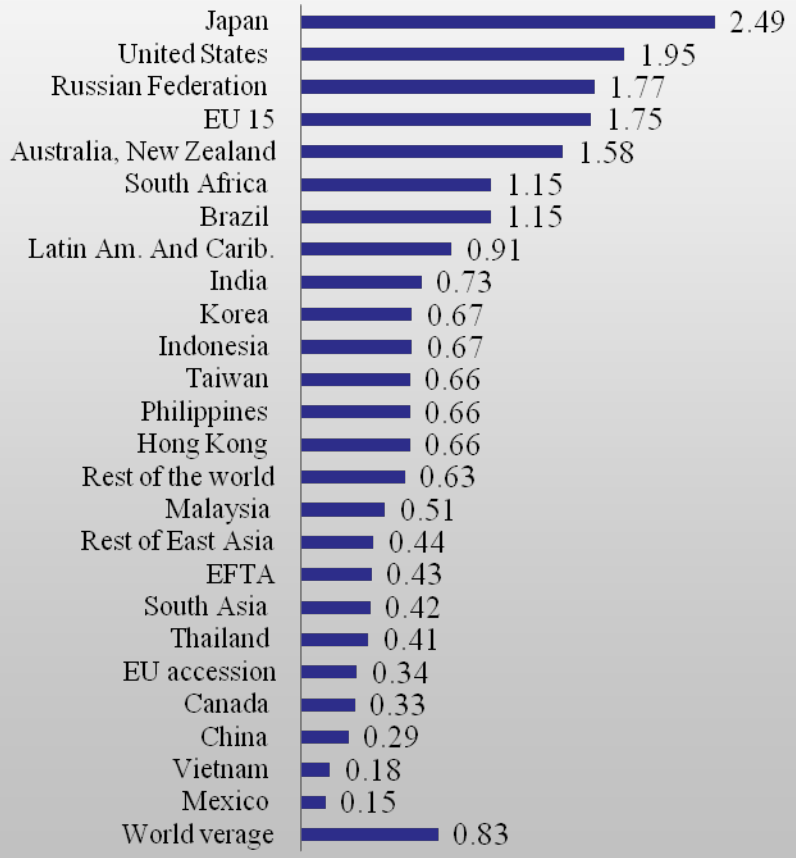


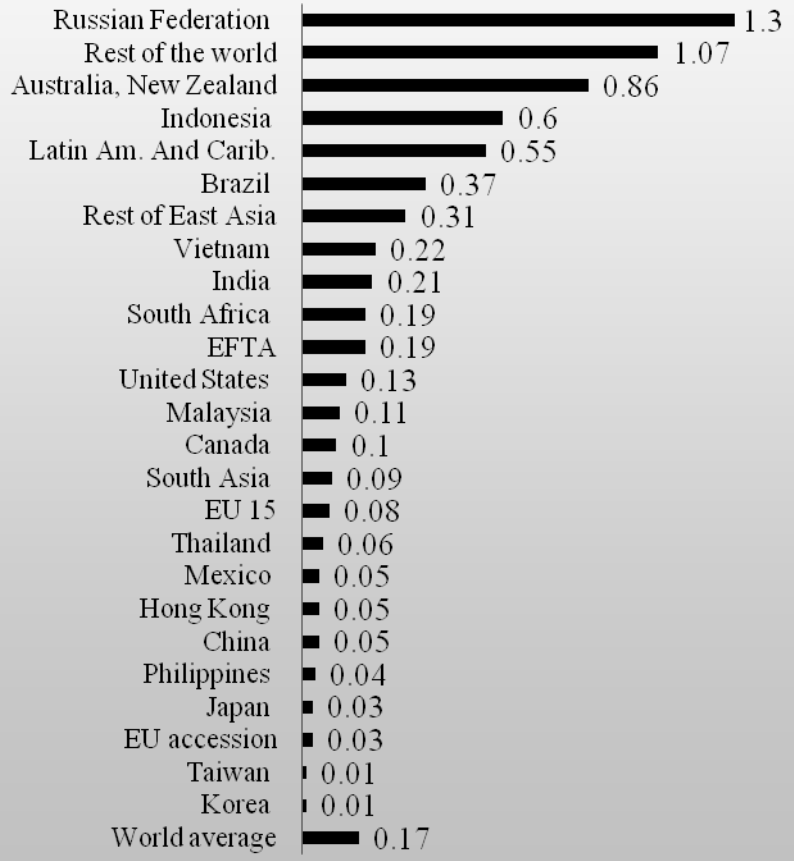
Global Value Chains - Position and Participation Indices



Broad Sector Structure of Value-added Exports
IV/FV Ratios

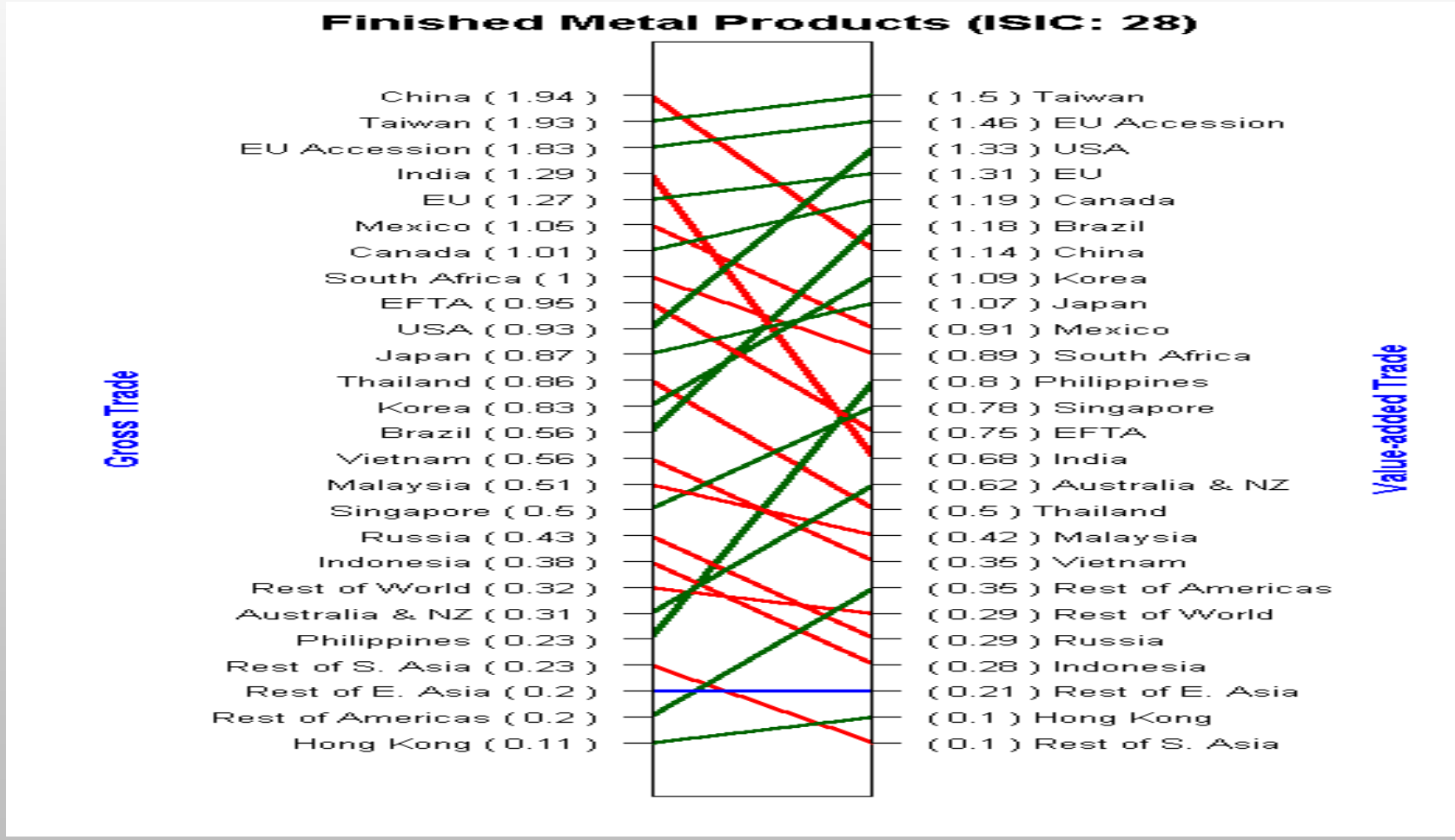


Manufacture and Services



Raw Materials

Value-added-adjusted Revealed Comparative Advantage Indicators



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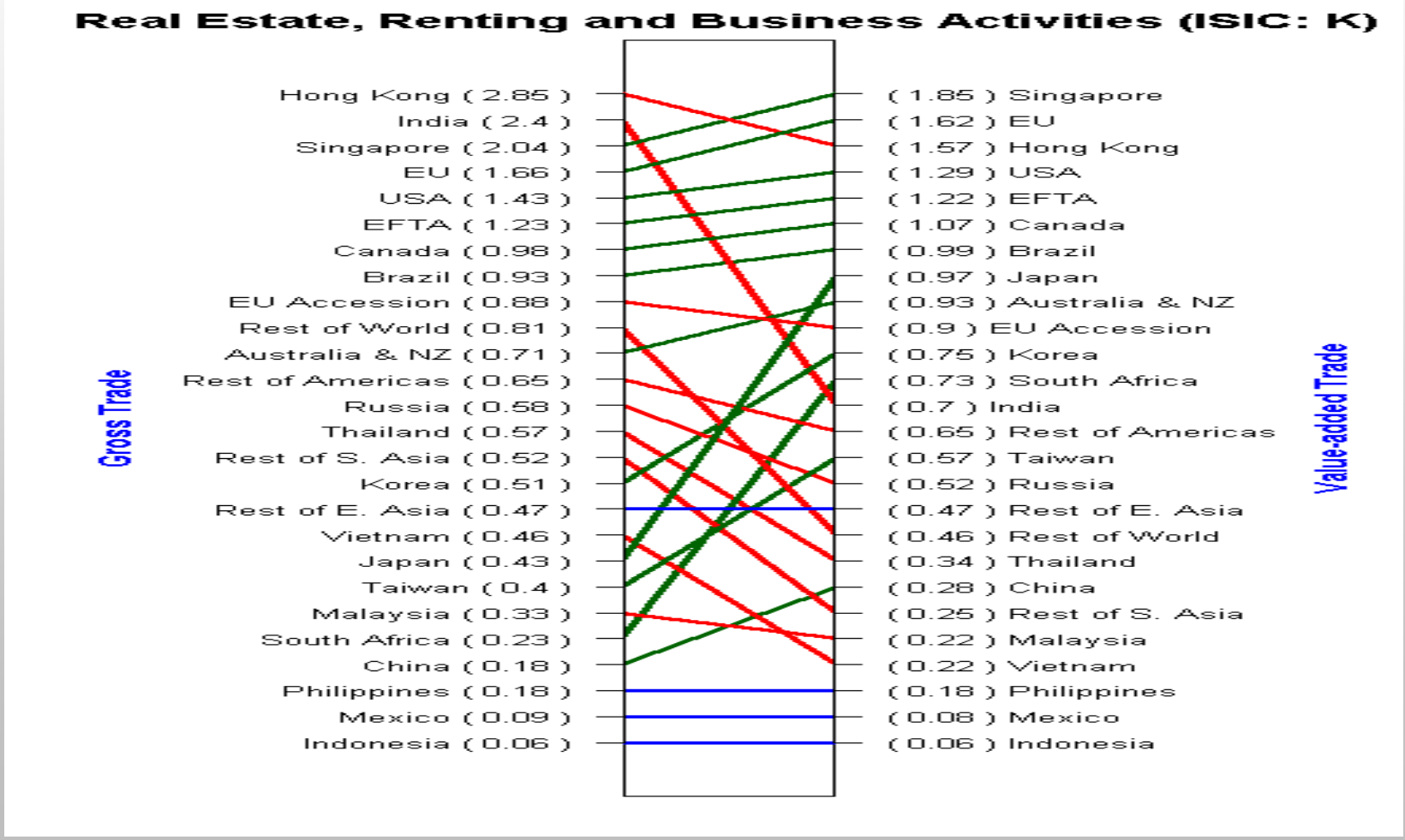
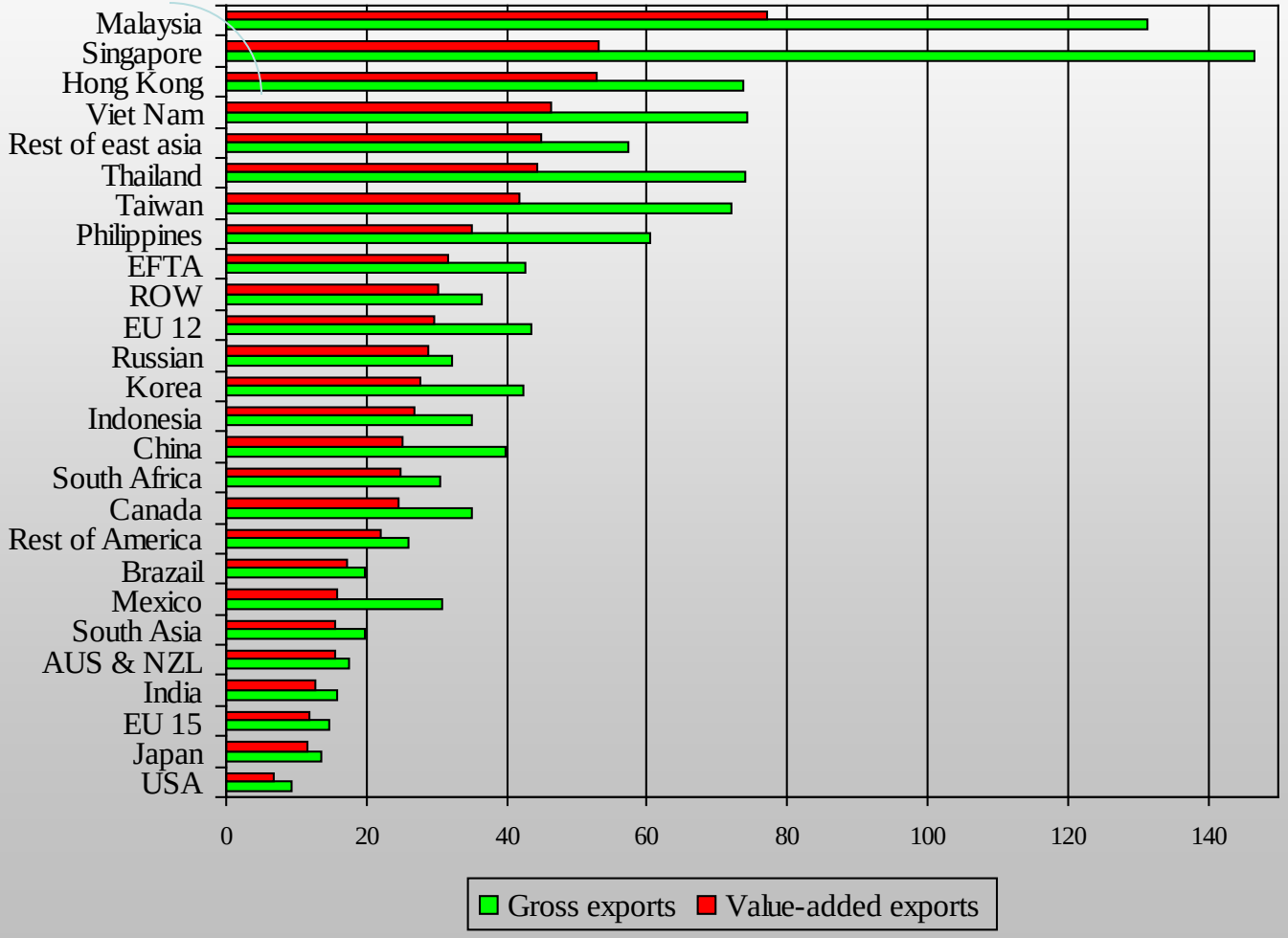


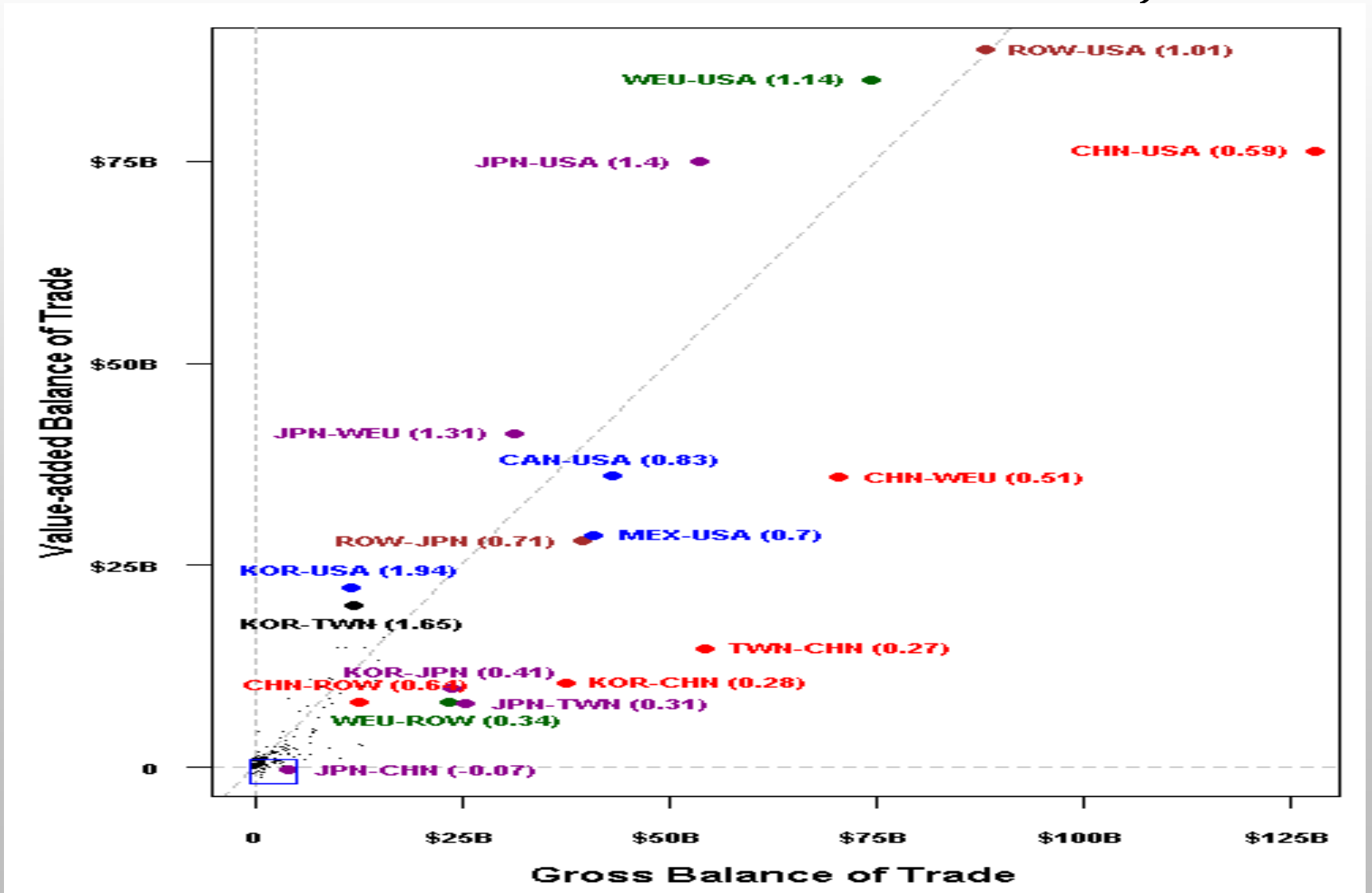
Gross Exports to GDP Ratio Overstate Exports Dependence

- *Gross and value-added exports as % of GDP, 2004*

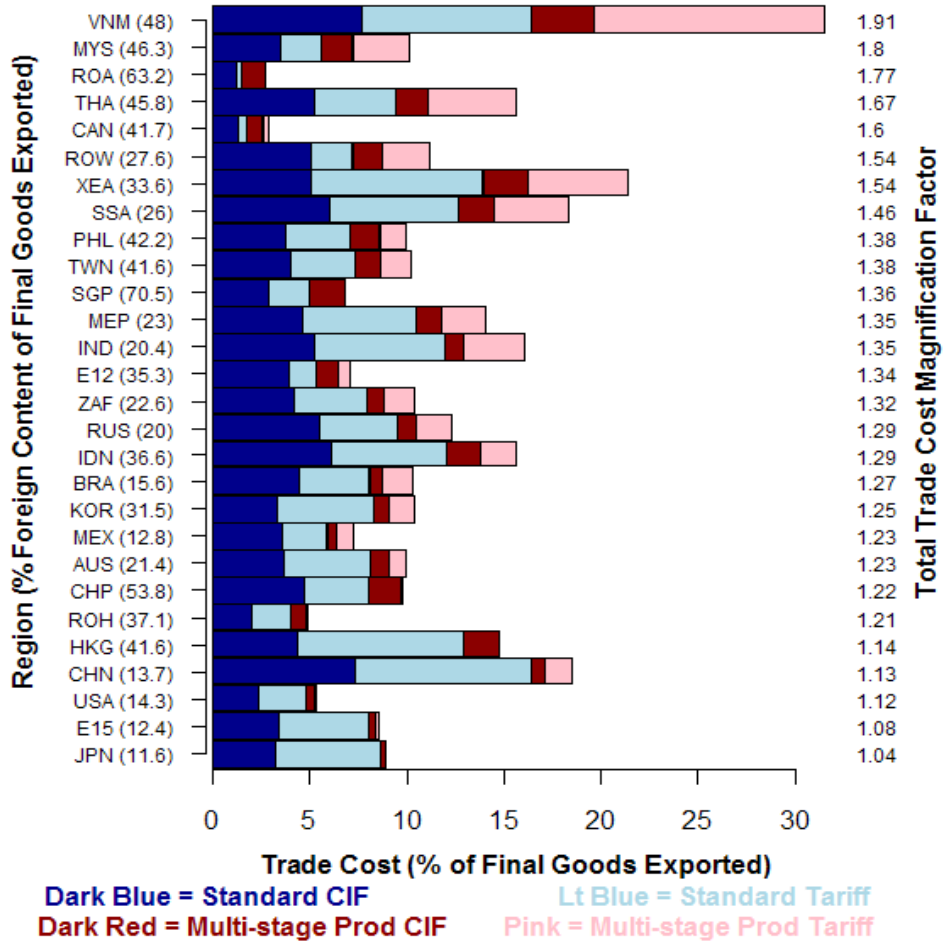


Data Source: Value-added trade estimate by the author based on version 7 GTAP database

Gross and Value-added Balance of Trade, 2004

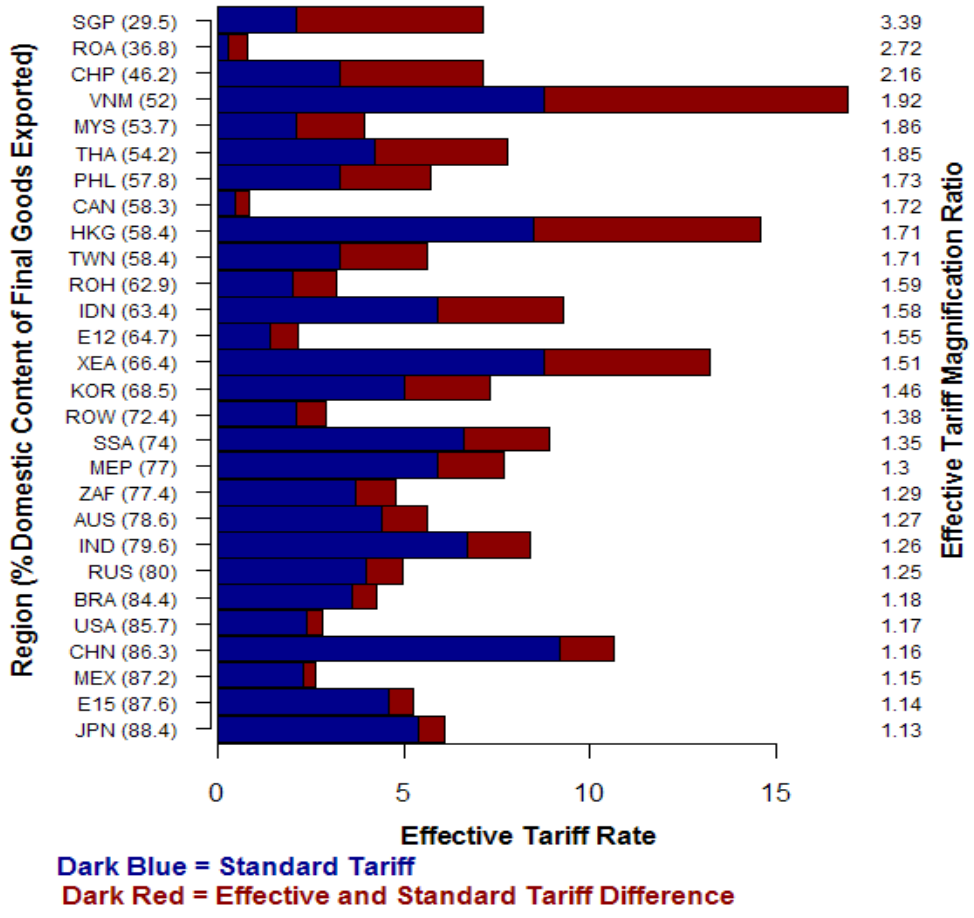


Trade costs of multistage production



- 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



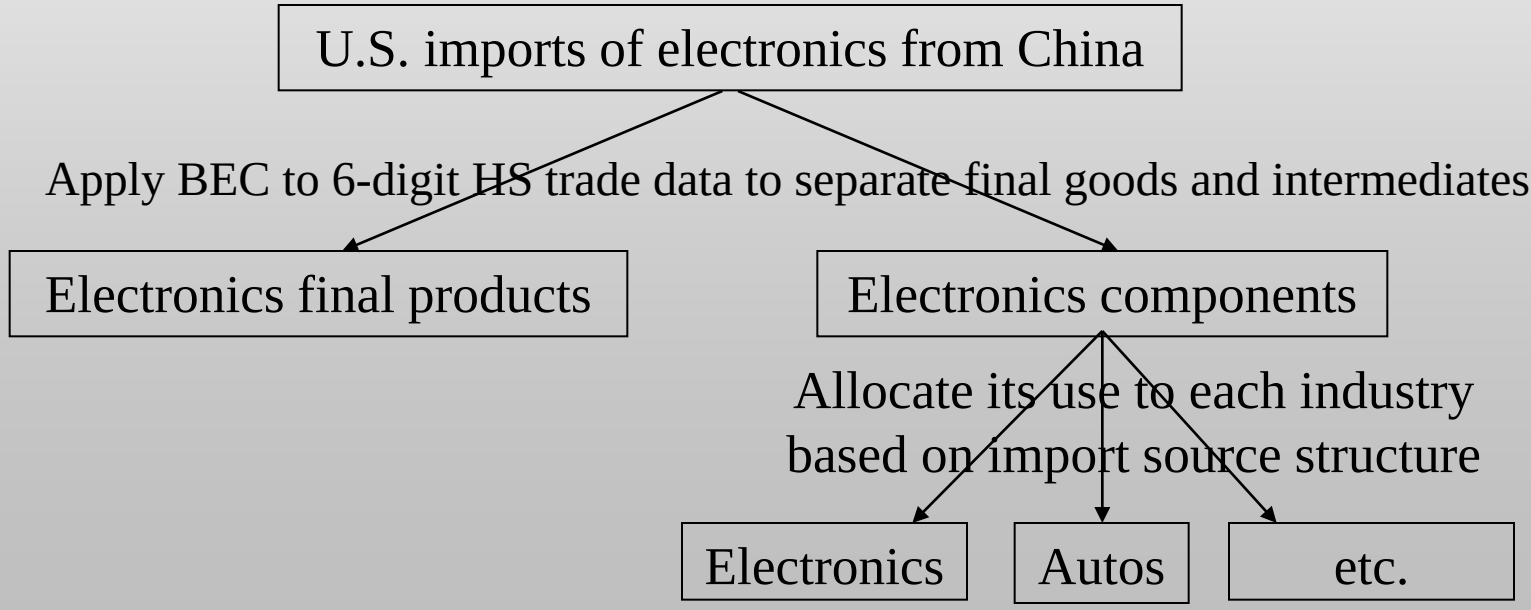
- Advanced economies have higher domestic content in their exports, hence their exporters face lower effective tariff rate

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

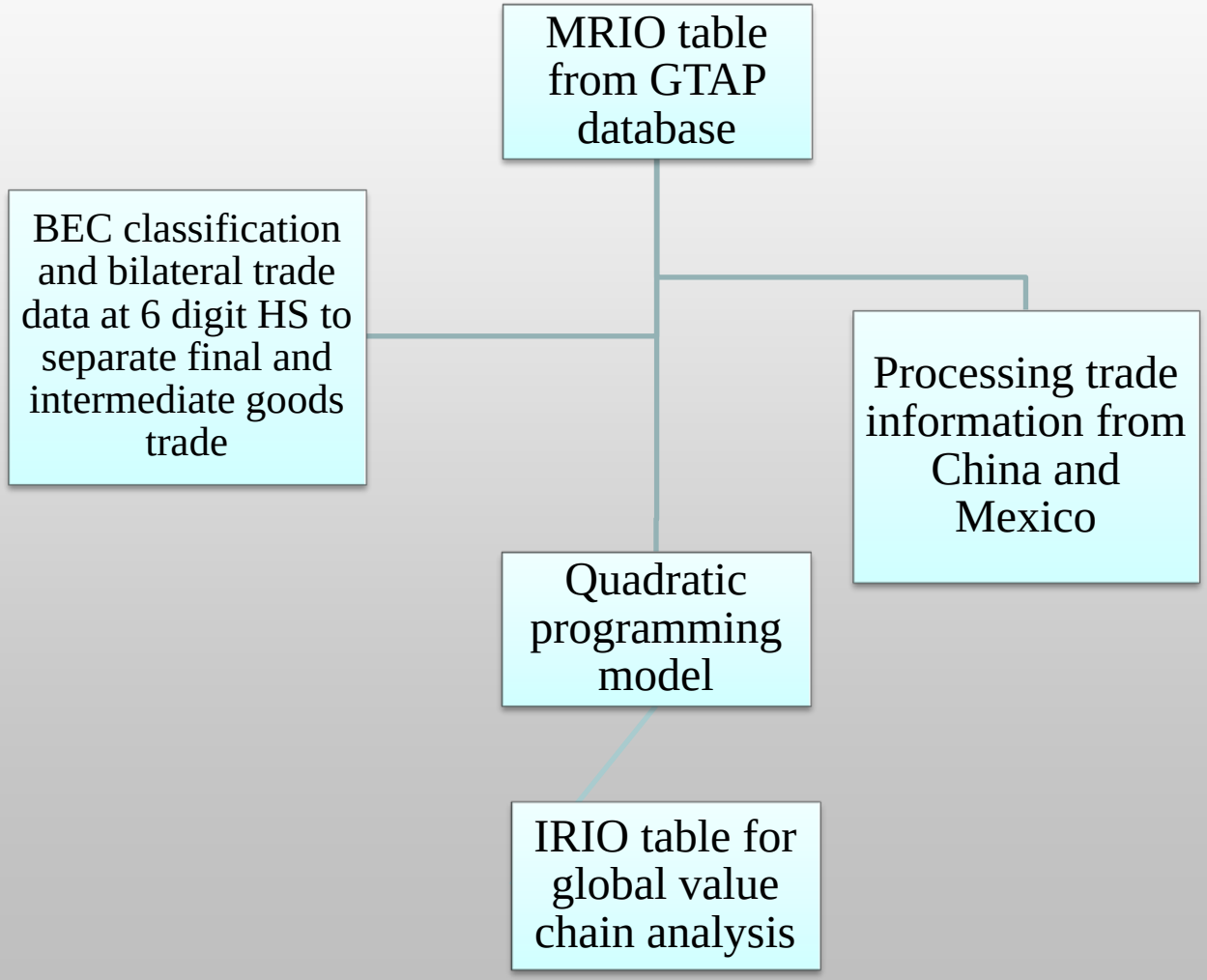
- Deep tariff cut in manufacturing sectors will benefit emerging economies more

Data Base Improvement: MCIO to ICIO

- Start with 2004 GTAP global trade and production database
- Add additional detail on source and use of intermediate inputs and final goods, Use end-use categories of detailed trade data (HS6) to improve imported intermediate use coefficients
- Add detail on processing imports for Mexico and China

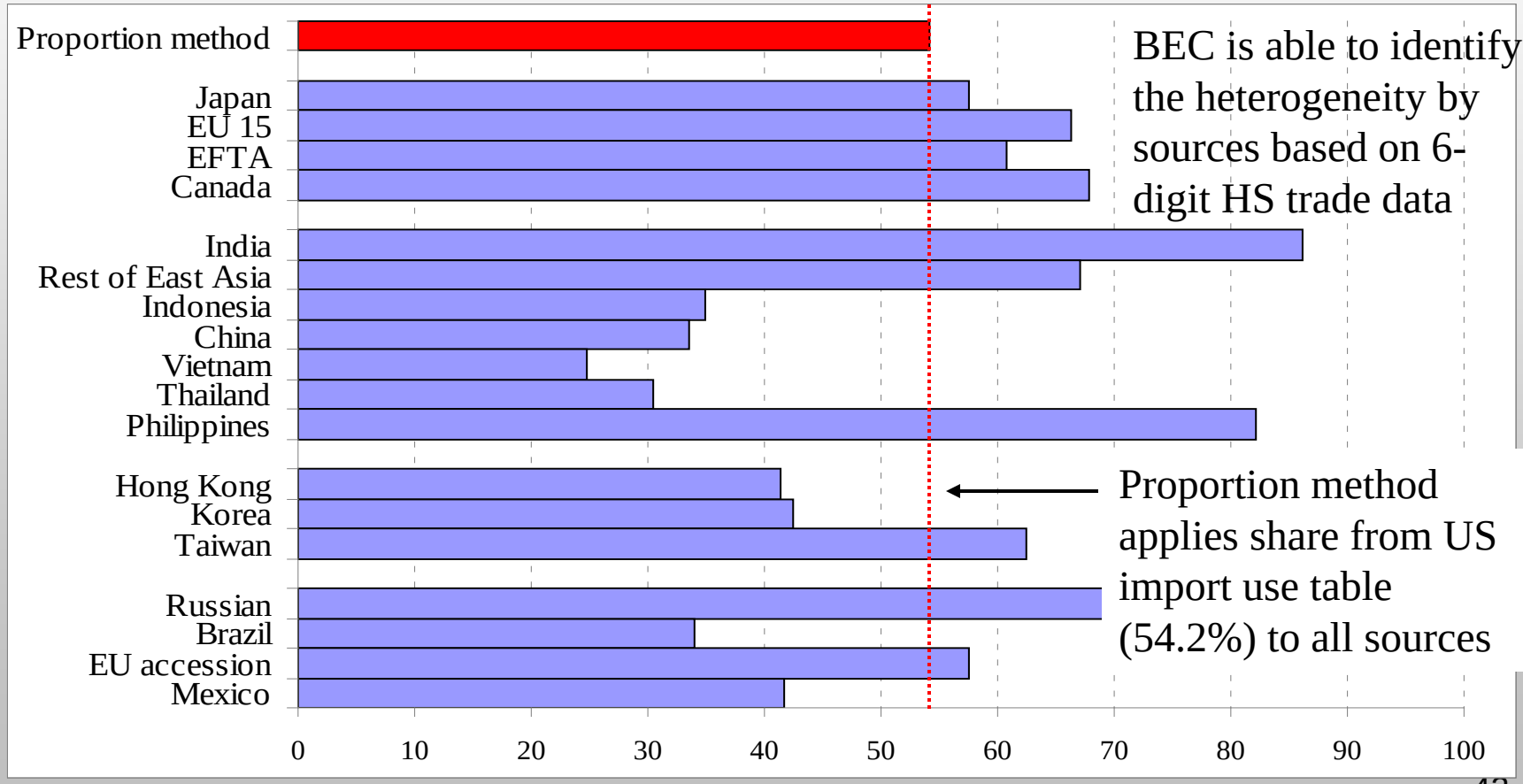


Database Construction: MRIO to IRIO Tables



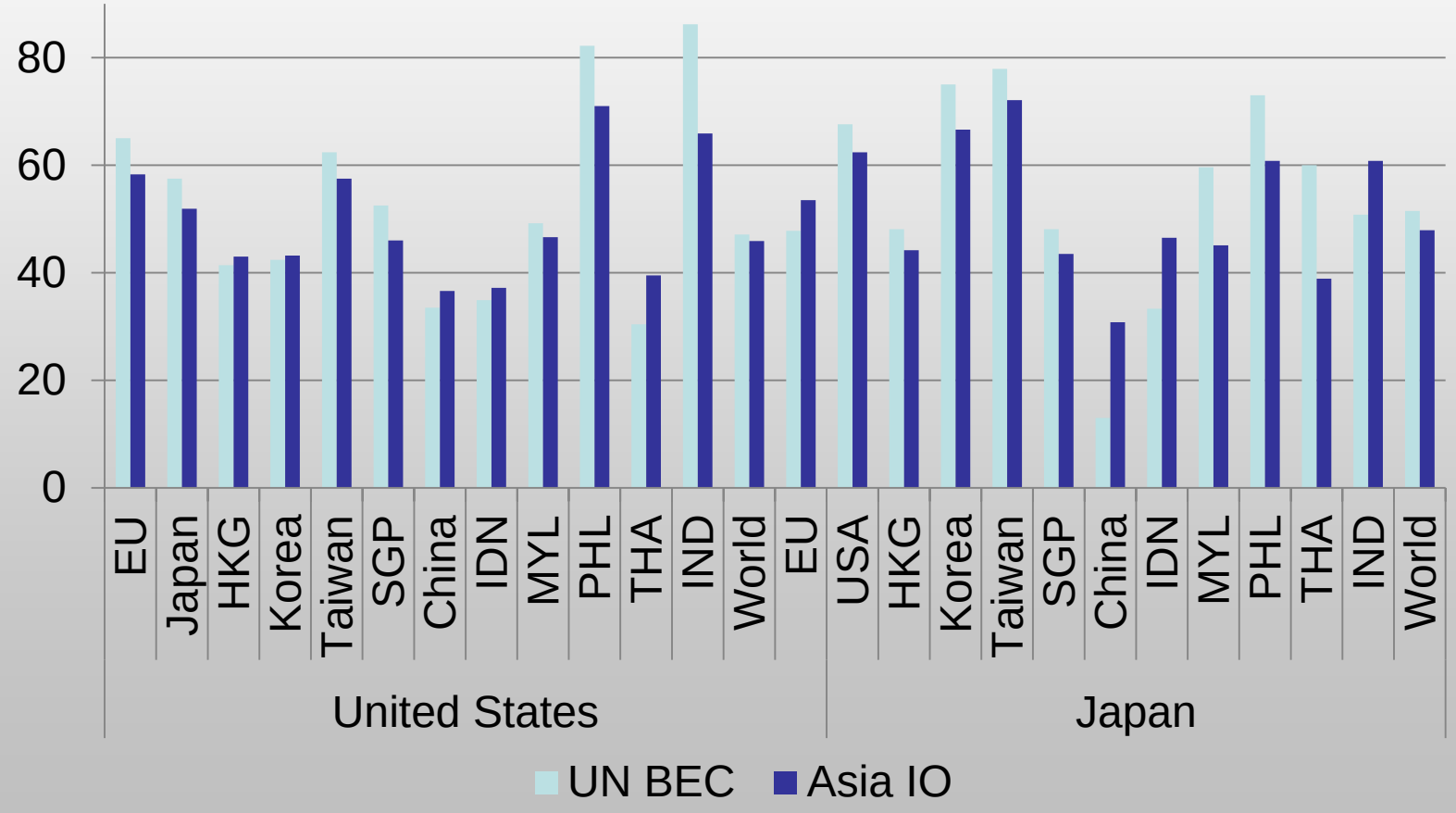
Why BEC is Better than Proportional Assumption

Intermediate share of U.S. electronic machinery imports, by source



Intermediate share of U.S. and Japanese electronic machinery imports by source

Comparing with data in Asia IO Table 2005



What end-use classifications can help

- Intermediate goods identified from gross trade flows are the row sum of each block matrix A_{rs} in the IO coefficient matrix A.
- End use classification such as BEC distinguishes intermediate inputs from final goods in imports from each source in each sector, thus can help improve the accuracy of IO coefficients in IRIO table by giving better row total control for each block matrix in A.
- End-use classifications improve estimates of intermediate inputs entering the importing country from each sources, therefore is better than the alternative: Proportional method assumes the intermediate share in imports from each source country are the same so it will bias the value-added estimates from each source country, even in aggregate.

What end-use classifications can't help

- Still have to assume proportionality to allocate intermediate inputs to each industry *within the importing country*
  - Required data not reported by most national statistical agencies
  - Problem noted by Committee on Economic Statistics of the American Economic Association (Feenstra et al., 2010)
- Industry-level estimates of value-added trade based on such IRIO table may be unreliable with unknown biases, despite their theoretical tractability
- To improve the sector level results,
  - Current end use classifications need to be extended to dual use products and services trade.
  - methods need to be developed to properly distribute imports to domestic users.

Conclusion

- Avoiding double counting is critical in value-added trade estimation, gross export decomposition naturally includes both the double counted items and the value added exports. Otherwise, the decomposition would be incomplete.
- Our decomposition method can simultaneously estimate :
  - value added exports
  - domestic content in exports, and
  - various double counted items in gross exports
- We hope these new measures could be widely used in analytical and policy work in comparison with gross trade data.

Conclusions

- We quantify the relation between domestic content in exports, value-added exports and gross exports
  - Harmonizes all related measures in the literature
  - Establishing a formal relationship between value-added measures and official trade statistics.
  - Provides illustrative applications that show the potential usefulness for these new measures to reshape our understanding of global trade.
- It may provide a feasible way for international statistical agencies to report value-added trade statistics regularly in a relatively low cost fashion.

Proof of equation (12)

- Based on equation (8) and using the relationship between X and Y as specified in the standard IO model

$$VT_{12} + V_1 B_{12} Y_{21} = V_1 B_{11} Y_{12} + V_1 B_{12} Y_{22} + V_1 B_{12} Y_{21} = V_1 B_{11} Y_{12} + V_1 B_{12} Y_2$$
$$= V_1 B_{11} Y_{12} + V_1 B_{12}[(I - A_{22}) X_2 - A_{21} X_1)] = V_1 B_{11} Y_{12} + V_1 B_{12}(I - A_{22}) X_2 - V_1 B_{12} A \quad (14)$$

- Based on the definition of inverse matrix, we could show

$$B_{12}(I - A_{22}) - B_{11} A_{12} = 0$$

$$V_1 B_{11} E_{12} = V_1 B_{11} Y_{12} + V_1 B_{11} A_{12} X_2 = V_1 B_{11} Y_{12} + V_1 B_{12}(I - A_{22}) X_2 \quad (15)$$

- Subtract equation (14) from (15) we obtain:

$$V_1 B_{11} E_{12} - VT_{12} = V_1 B_{12} Y_{21} + V_1 B_{12} A_{21}$$