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

Robert Koopman and Zhi Wang US International Trade Commission

Shang-Jin Wei Columbia University, NBER, and CEPR

China is extraordinarily open and increasingly so! Exports/GDP Ratio for China, India and the U.S.:1977-2006



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



Presentation Outline

- 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"

- Chen, X., L. Cheng, K.C. Fung and L. J. Lau. 2004
- Lau L.J., X. Chen, L. K. Cheng, K. C. Fung, Y. Sung, C. Yang, K. Zhu, J. Pei and Z. Tang. 2007

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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5、加工贸易类别: 三资进料加工	6、出口制成品返销截止日期; 2008.03.05
进 7、进口合同号: (2007) 1号	来 10、合作外商:
料 8、出口合同号: (2007) 1号 加	料 11、合同号:
エ 9、客供辅料合同号:	工 12、加工费(美元):
13、进口主要料件(详细见目录清单):	16、出口主要制成品(详细见目录清单):
14、进口料件总值(美元): \$959577.0 国内购买料件总值(美元): \$0.0	17、出口制成品总值(美元): \$1192260.0
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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

$$(1) \qquad A^D X + Y^D = X$$

$$(2) \qquad A^M X + Y^M = M$$

$$(3) \quad uA^D + uA^M + A_v = u$$

Total production = dom sale +exports Total imports = final sale + use as intermediates

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

 $AD = [a_{ij}^{D}] =$ matrix of direct input coefficients of domestic products; $AM = [a_{ij}^{M}]$ is an matrix of direct input coefficients of imported goods;

- $A^{D} = [a^{D}_{ij}] =$ matrix of direct input coefficients of domestic products;
- $A^{M} = [a^{M}_{ij}]$ is an matrix of direct input coefficients of imported goods;
- Y^D = vector of final demands for domestically produced products, including usage in gross capital formation, private and public consumption, and gross exports;
- Y^M = vector of final demands for imported products, including usages in gross capital formation, private and public final consumption;
- X is a vector of gross output;
- *M* is a vector of imports;
- A^v = [a^vj] is a 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:

$$X = (I - A^{D})^{-1} Y^{D}$$
$$\Delta (M - Y^{M}) = A^{M} (I - A^{D})^{-1} \Delta Y^{D}$$
$$DVS = \stackrel{\wedge}{A_{v}} \Delta X / \Delta Y^{D} = \stackrel{\wedge}{A_{v}} (I - A^{D})^{-1}$$

 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:

$$DVS = \Delta V / \Delta Y^{D} = A_{v} \Delta X / \Delta Y^{D} = A_{v} (I - A^{D})^{-1}$$

- □ Share of foreign content:
- FVA = 1- DVA

Intuition behind the DVA share formula : $DVS = A_v + A_v A^D + A_v A^D A^D + A_v A^D A^D + \dots$ $= A_v (I + A^D + A^{D^2} + A^{D^3} + \dots)$

• 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):

$$FVS = u - DVS = u - A_v^{\wedge} (I - A^D)^{-1}$$

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

= HIY's 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

$$(1) \qquad A^D X + Y^D = X$$

$$(2) \qquad A^M X + Y^M = M$$

Total production = dom sale +exports Total imports = final sale + use as intermediates

(3)
$$(A^{D} + A^{M})'X + A_{v}X = X$$

(4) $uA^{D} + uA^{M} + A_{v} = u$

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

 $AD = [a_{ij}^{D}] =$ matrix of direct input coefficients of domestic products; $AM = [a_{ij}^{M}]$ is an matrix of direct input coefficients of imported goods;

$$A^{DD} = [a_{ij}^{dd}] = [\frac{z_{ij}^{dd}}{x_j - e_j^p}] \quad A^{MD} = [a_{ij}^{md}] = [\frac{z_{ij}^{md}}{x_j - e_j^p}] \quad A_v^D = [a_j^{vd}] = [\frac{v_j^d}{x_j - e_j^p}]$$

$$A^{DP} = [a_{ij}^{dp}] = [\frac{z_{ij}^{dp}}{e_j^p}], A^{MP} = [a_{ij}^{mp}] = [\frac{z_{ij}^{mp}}{e_j^p}], A_v^P = [a_j^{vp}] = [\frac{v_j^p}{e_j^p}]$$

A and Z matrices and linear transformation of each other

IO table with separate account for processing trade

			Intermediate use		Final use	
			Production for domestic use & normal exports	Production of processing exports	Final use C+I+G+E	Gross Output or Imports
	1	DIM	1,2,, N	1,2,, N	1	1
Domestic Intermediate Inputs	Production for domestic use & normal exports (D)	1 N	Z^{DD}	Z^{DP}	Y^D	$X - E^{P}$
	Processing Exports (P)	1 N	0	0	E^{P}	E^{P}
Intermediate I Imports	nputs from	1 N	Z^{MD}	Z^{MP}	Y^M	M
Value-added		1	V^D	V^{P}		
Gross output		1	$X-E^{P}$	E^{P}		

Re-worked model when processing trade is recognized

^(1*)
$$A^{DD}(X - E^{P}) + A^{DP}E^{P} + Y^{D} = X$$

(2*)
$$A^{MD}(X - E^{P}) + A^{MP}E^{P} + Y^{M} = M$$

(3*)
$$(A^{DP} + A^{MP})' E^{P} + A^{P} A^{P} E^{P} = E^{P}$$

(4*)
$$(A^{DD} + A^{MD})'(X - E^{P}) + \hat{A}^{D}_{\nu}(X - E^{P}) = X - E^{P}$$

(5*)
$$uA^{Dk} + uA^{Mk} + A_{v} = u, \qquad k = D, P$$

Imported VA Share/Foreign content: generalize HIY

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

$$\overline{VSS} = \begin{vmatrix} VSS^{D} \\ VSS^{P} \end{vmatrix}^{T} = \begin{vmatrix} uA^{MD}(I - A^{DD})^{-1} \\ uA^{MD}(1 - A^{DD})^{-1}A^{DP} + uA^{MP} \end{vmatrix}^{T}$$

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

$$TVSS = uA^{MD} (I - A^{DD})^{-1} \frac{E^{N}}{te} + u(A^{MD} (1 - A^{DD})^{-1} A^{DP} + A^{MP}) \frac{E^{P}}{te}$$

- 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

$$\overline{DVS} = \begin{vmatrix} DVS^{D} \\ DVS^{P} \end{vmatrix}^{T} = \begin{vmatrix} A_{V}^{D} (I - A^{DD})^{-1} \\ A_{V}^{D} (1 - A^{DD})^{-1} A^{DP} + A_{V}^{P} \end{vmatrix}^{T}$$

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:

Level of foreign content is substantially under-estimated;
 "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



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^{0.0}
- 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



Domestic Content by Manufacture Sector (3) Selected High DVA (low foreign content) share industries, in %, 2002



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)

	C, steel	C, tools	C, final	US, steel	US, tools	US, final	EU
C, steel							
C, tools							
US, steel							
US, tools							
EU, steel							
EU, tools							

The model with an Inter-regional Input-output Table

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

Total production = dom sale +exports

(2)
$$\sum_{s=1}^{M} \sum_{i=1}^{N} z_{ij}^{sr} + \sum_{s=G-M}^{G} \sum_{i=1}^{N} m_{ij}^{sr} + v_{j}^{r} = x_{j}^{r}$$

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

$$DVS = \Delta V / \Delta Y^{D} = A_{v} \Delta X / \Delta Y^{D} = A_{v} (I - A^{D})^{-1}$$

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.)

Year	Indon esia (3)	Japan (4)	Korea (5)	Malay- sia (6)	Taiwan (7)	Philip- pines (8)	Singa- pore (9)	Thai- land (10)	United States (11)	Hong Kong (12)	Rest of World (13)	Total (14)
1990	1.1	13	1.4	1.7	3.5	0.1	0.4	0.9	6.7	51.3	20	100
2000	1.6	15.5	8.4	1.6	7.9	0.5	1.2	1	8.9	10.5	42.9	100

- 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

Industries (1)	Export Value in 2002 (in million dollars) (2)	Share in 's Manuf. Exports (%) (3)	Share of processing exports (%) (4)	Domestic Content Share (%) (5)	Foreign Content Share (%) (6)
Television, radios, audios & communication equipment	32,713	10.2	89.8	35.0	65.0
Electronic computing equipment	22,450	7.0	99.1	16.9	83.1
Wearing apparel	22,450	7.0	45.1	67.0	33.0
Knitting	18,601	5.8	31.6	72.9	27.1
Lighting fixtures, batteries, wiring and others	17,960	5.6	66.8	46.1	53.9
Other manufacturing products	16,036	5.0	64.2	55.0	45.0
Leather and leather products	14,432	4.5	54.3	48.8	51.2
Metal products	14,111	4.4	43.2	57.9	42.1
Other electronics and electronic products	13,791	4.3	93.4	19.2	80.8
General machinery	11,225	3.5	43.7	58.5	41.5
Semiconductors and integrated circuits	10,904	3.4	89.7	22.2	77.8
Wooden furniture	8,980	2.8	36.7	76.3	-23.7
Plastic products	7,697	2.4	64.5	37.6	62.4

Industries	Forei gn	ForeiSources of Foreign Value Added in 's Exportsgnto the in 2000								
	Conte nt Share (%)	Japan	Korea	Taiw an	Singa- pore	Other ASEA N	US	НК	EU 15	RO W
(1)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Television, radios, audios & communication equipment Electronic computing	65.0	16.2	7.2	7.8	1.8	4.6	11.1	16.9	16.5	17.8
equipment	83.1	15.9	7	8.3	2.6	6.5	12.6	16.5	13	17.6
Wearing apparel	33.0	19.4	10.6	10.3	0.6	3.9	6.1	7.3	9.7	32.1
Knitting	27.1	17	10.3	10	0.4	4.1	5.5	8.5	8.9	35.4

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.

