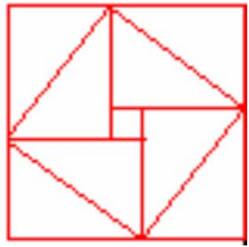


The Bias in Measuring Vertical Specialization

Zhu Kunfu

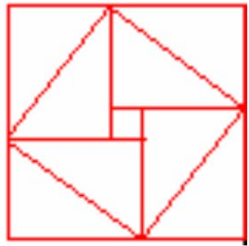
Academy of Mathematics and Systems Science, CAS, Beijing 100190

Co-authors: Yang Cuihong, Erik Dietzenbacher, Pei Jiansuo, Chen Xikang,
Tang Zhipeng



Outline

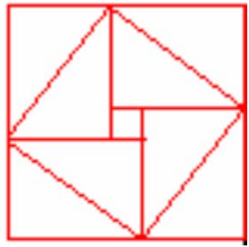
- **Introduction**
- **Vertical specialization by input-output model**
- **A new model capturing processing trade**
- **Adapting the Methodology**
- **The results**
- **Conclusion**



Introduction-1

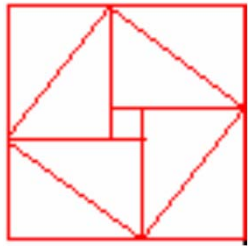
- **China's trade situation, especially after China's entry to the WTO in 2001. For example, during 2001-2006:**
 - ❖ **Growth rate of gross value of import and export: 25-30%;
Average annual growth rate: 28.1%**
 - ❖ **Trade volume/GDP: increase from 38.7% in 1995 to 69.1% in 2006.**
- **Processing of foreign goods: 55% of China's total exports in 2005, 2006.**

This index has been overestimated because of the special structure of China's foreign trade



Introduction-2

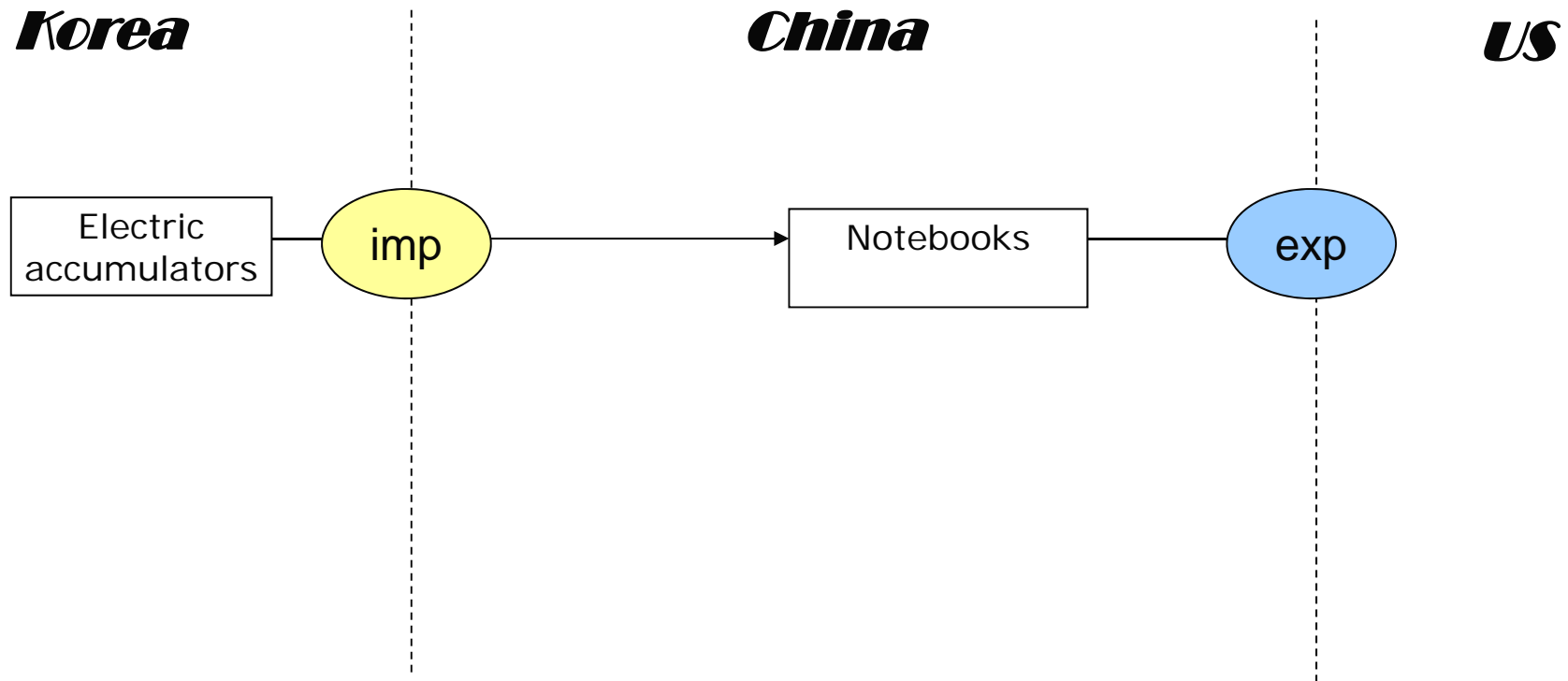
- **Processing trade, mainly by foreign-invested enterprises (FIEs), use imported raw material, spare and accessory parts to manufacturing products and then export**
- **Two types: PIM (processing with imported materials), PCM (processing with customer's materials)**
- **For PCM, China can only obtain a very low proportion of processing fee. 23% in 2007**
- **For PIM, the domestic content share is 44% in 2007**



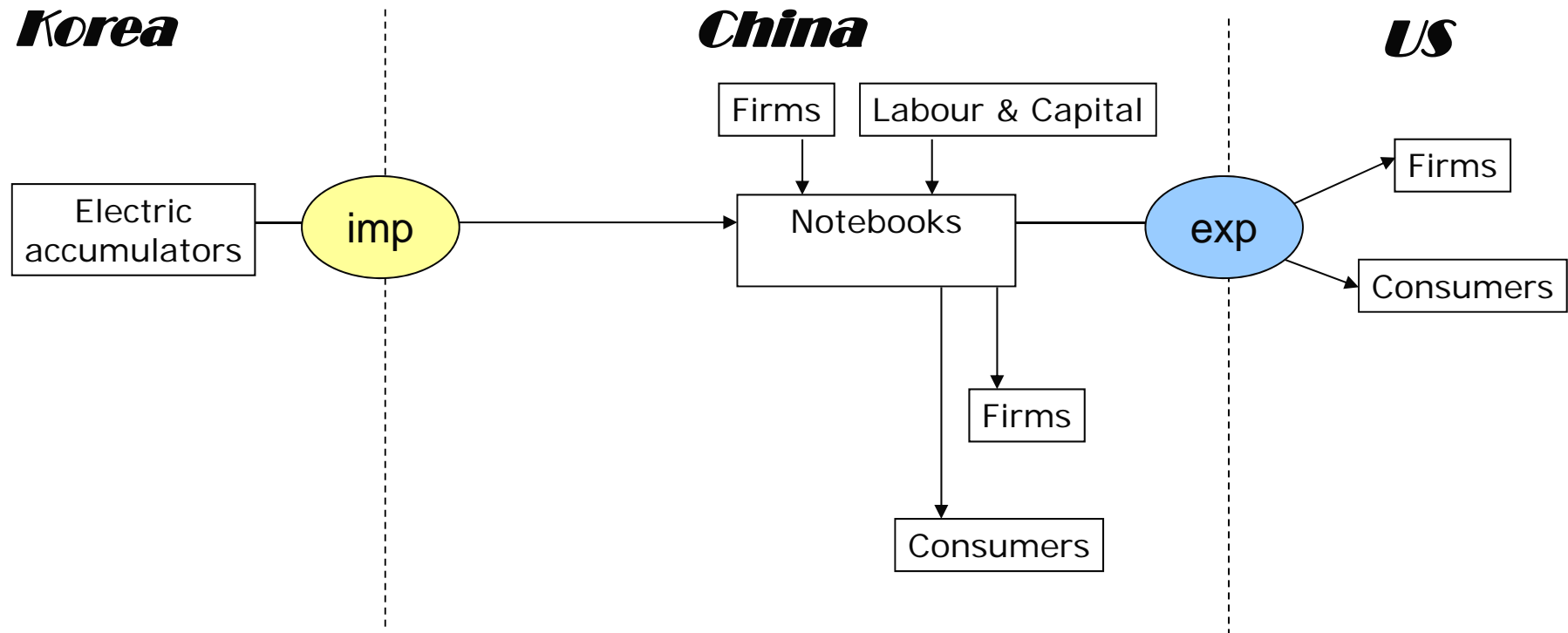
Introduction-3

- **International fragmentation has great impact on China's foreign trade, it has a high import dependency.**
- **Trade Literature: much attention for trade in *intermediate* goods**
- **Vertical specialization or international fragmentation**
 - ❖ **Production processes are more and more interconnected across many countries**
 - ❖ **each country specializes in particular stages of a good's production sequence**

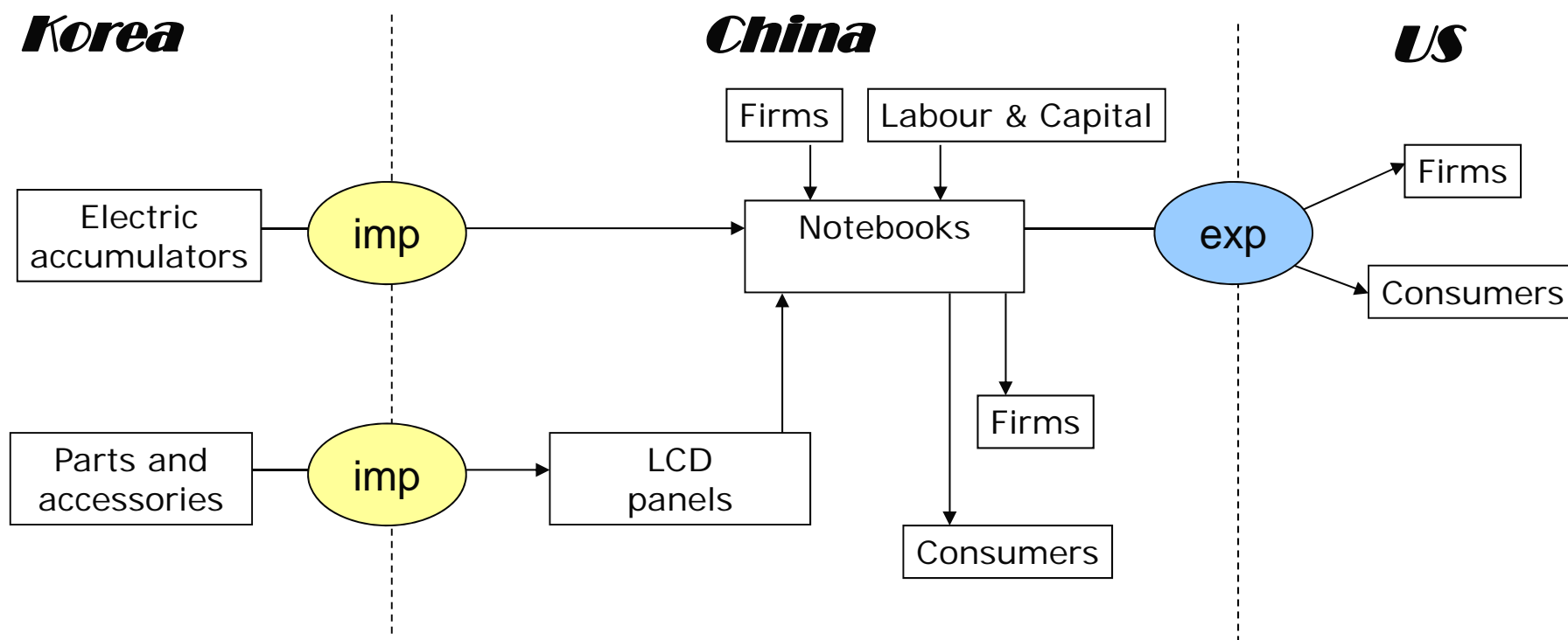
Vertical specialization, an example



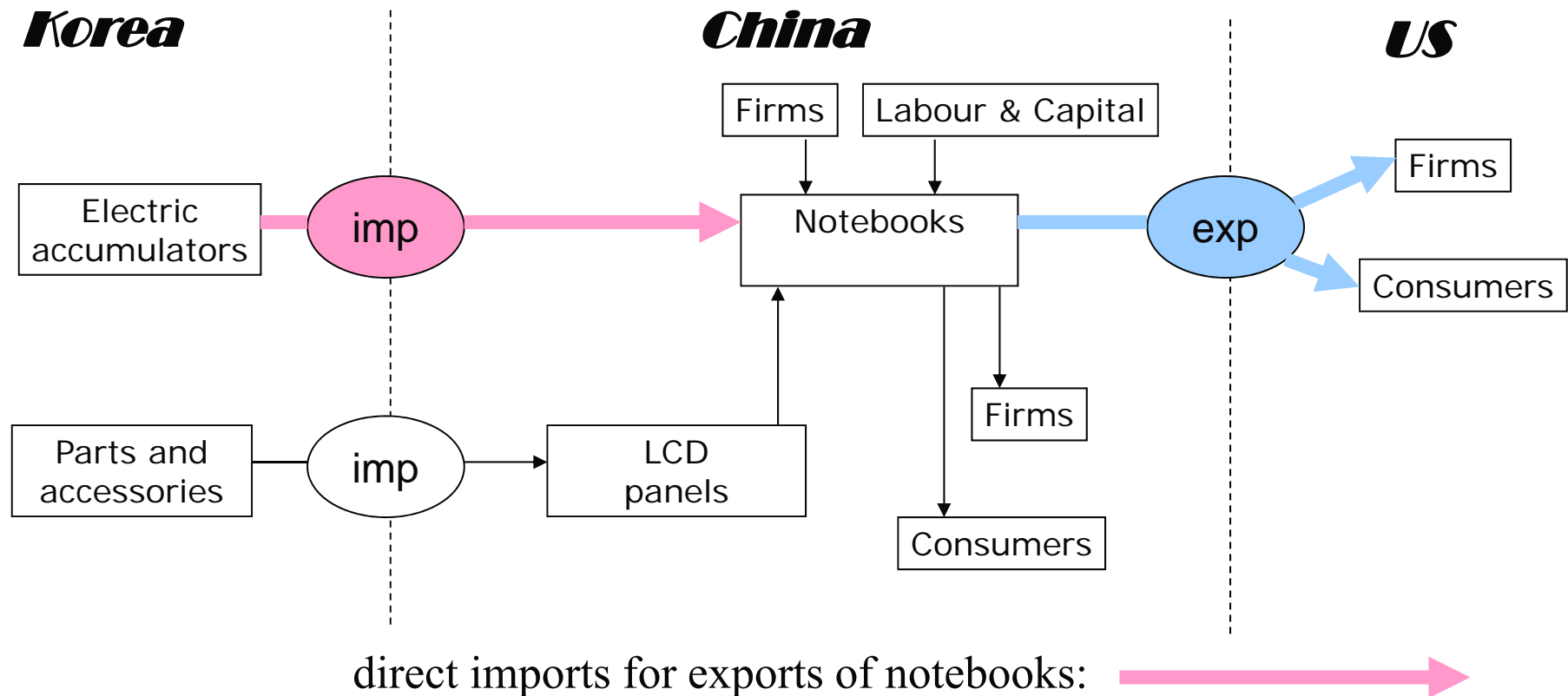
Vertical specialization, an example



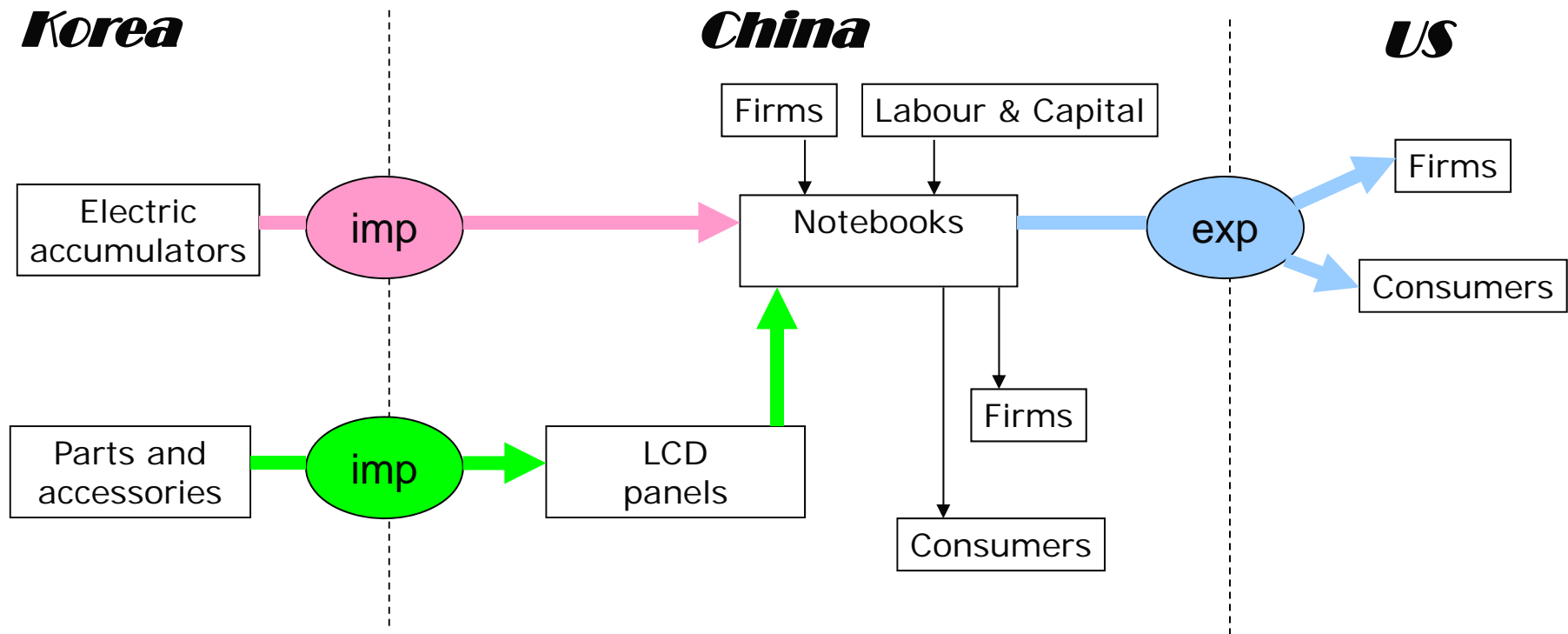
Vertical specialization, an example





Vertical specialization, an example

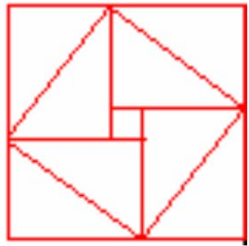


Vertical specialization, an example



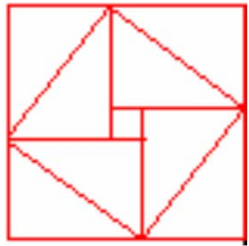
direct imports for exports of notebooks: 

indirect imports for exports of notebooks: 



Vertical specialization by input-output model

- **Adopt vertical specialization (VS) to illustrate the import dependency of China's foreign trade(Hummels, etc 2001)**
 - ❖ **measure for VS in a country based on input-output tables**
 - ❖ **VS measure: import content of the exports**



Vertical specialization by input-output model

Z	f	e	x
M			
V'			
x'			

M = matrix with imports

m_{ij} = imports of good i
by industry j

v' = row vector with
value added

v_j = value added in industry j

Z = matrix of intermediate deliveries

z_{ij} = delivery from industry i to
industry j

f = vector of domestic final demands

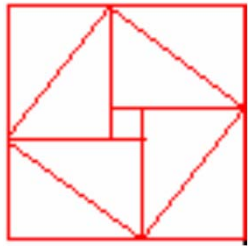
f_i = domestic final demand for good i
= consumption, investments, inventory
change

e = vector of exports

e_i = exports of good i

x = vector of gross output

x_i = gross output in industry i



Vertical specialization by input-output model

Z	f	e	x
M			
V'			
x'			

Definition of coefficients

A = matrix of domestic input coefficients

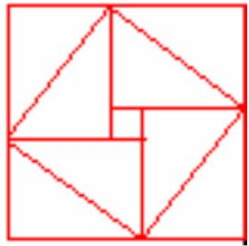
$a_{ij} = z_{ij}/x_j$
= input of i per unit (Rmb) of
output in industry j

B = matrix of direct import coefficients

$b_{ij} =$ import of i per unit of output in j

Direct import multiplier λ_j

$\lambda_j = \sum_i b_{ij} =$ total imports per unit of output in industry j



Direct VS share

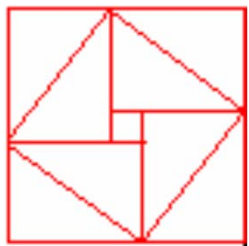
Consider exports e_j of good j
they have been produced in China
hence the direct imports amount to: $\lambda_j e_j$

The direct imports corresponding to *all* exports: $\sum_j \lambda_j e_j$

Measure for *direct* vertical specialization share (DVS)
ratio of direct imports corresponding to exports
over the total exports

$$DVS = \frac{\sum_j \lambda_j e_j}{\sum_j e_j} = \frac{\lambda' \mathbf{e}}{\mathbf{u}' \mathbf{e}} = \frac{\mathbf{u}' \mathbf{B} \mathbf{e}}{\mathbf{u}' \mathbf{e}}$$

\mathbf{u} is the summation vector
consisting of ones. \mathbf{B} is the direct
import input coefficient matrix



Total VS share

Define: $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$

One unit exports good j yields:

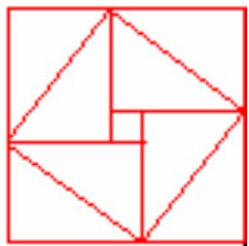
l_{ij} output in industry i

$\lambda_j = \sum_i b_{ij} =$ total imports per unit of output in industry j

hence $\lambda_i l_{ij}$ of imports by industry i

$i = 1, \dots, n$, hence total imports $\sum_i \lambda_i l_{ij}$

Total import multiplier $\mu_j = \sum_i \lambda_i l_{ij}$



Total VS share

Total import multiplier $\mu_j = \sum_i \lambda_i l_{ij}$: total amount of imports that is required (directly and indirectly) per unit of exports of good j

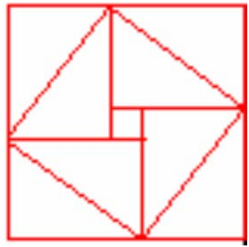
Exports of good j are e_j , this requires $\mu_j e_j$ of imports

All exports thus require $\sum_j \mu_j e_j$ of imports

Measure for *total vertical specialization* (TVS)

ratio of direct plus indirect imports corresponding to exports over the total exports

$$TVS = \frac{\lambda'Le}{u'e} = \frac{u'BLE}{u'e}$$



Summary

➤ **Two measures for vertical specialization share**

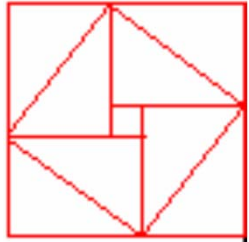
$$\text{direct: } DVS = \frac{\sum_j \lambda_j e_j}{\sum_j e_j} \quad \text{total: } TVS = \frac{\sum_j \mu_j e_j}{\sum_j e_j}$$

➤ **Input-output table for China in 2002** (27 industry sectors)

$$DVS = 0.15 \quad \text{and} \quad TVS = 0.25$$

100 Rmb of exports require on average

15 Rmb of imports directly, 25 Rmb of imports in total



Comparison with other counties

$TVS = 0.25$ (China, 2002)

	1995	2000	
Australia	0.15	----	high
Brazil	0.11	0.13	medium
Canada	0.32	0.31	low
China	0.20	0.20	
Denmark	0.23	0.21	
France	0.20	0.21	
Germany	0.21	0.26	
Japan	0.09	0.11	
Netherlands	0.34	0.37	
United Kingdom	0.23	0.21	
United States	0.10	0.12	

Source: MSc thesis of ZHAO Bing (University of Groningen)

OECD input-output tables for 1995 and 2000 for 48 industries

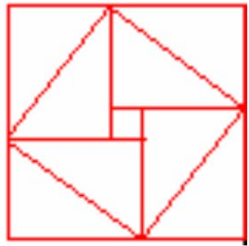


Table 1 Import dependency ratio of processing export with imported materials (PIM) ---by FIEs as an example (%)

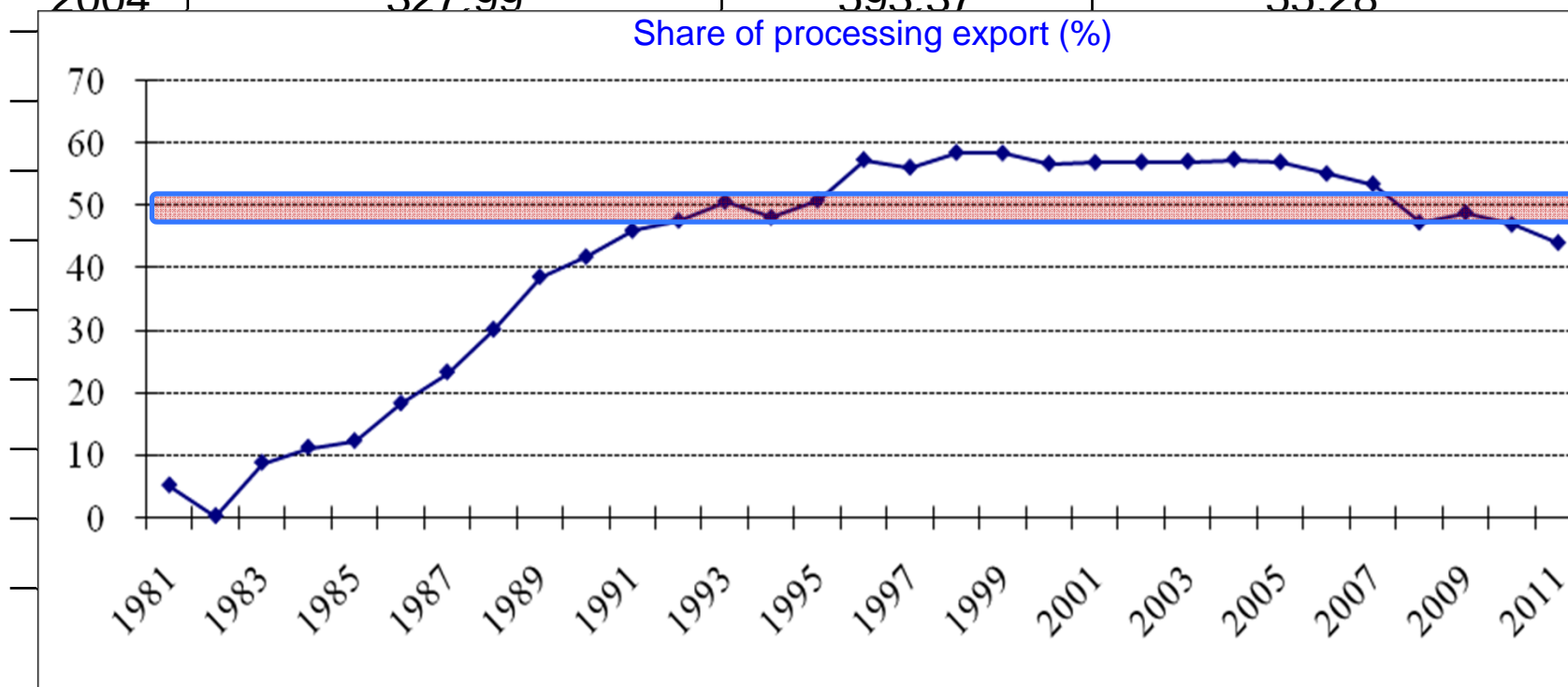
Year	Import dependency ratio	Year	Import dependency ratio
1990	90.15	1999	70.58
1991	92.55	2000	70.03
1992	91.92	2001	64.54
1995	87.83	2002	69.11
1996	77.70	2003	68.37
1997	74.39	2004	66.43
1998	69.74		

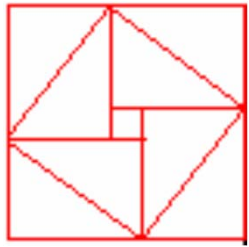
Source: Calculated by the author according to Wang & Lv, 2005

Wang Hongqing, Lv Likang (2005), *Inward Foreign Direct Investment and China's Processing Trade, Reform (Gai Ge)*, No. 7, 77-81 (in Chinese)

Share of Processing Exports in total exports value of China 2001-2011

	Total value of Processing Exports (US\$ billion)	Total Exports Value (US\$ billion)	Ratio of Processing Exports on Total Value of Exports (%)
2001	147.45	266.15	55.40
2002	179.94	325.57	55.27
2003	241.85	438.37	55.17
2004	327.99	593.37	55.28





-
- **China's VS is quite in the middle, much lower than expected**
 - **In general IO table, processing trade is 'hidden'**

Domestically Produced Intermediate Input Coefficients and Imported Intermediate Input Coefficients in Some Sectors of China in 2002

	Telecommunication equipment, computer and other electronic equipment			Electric equipment and machinery		
	D	P	N	D	P	N
Sum of domestically produced intermediate input coefficients	0.7108	0.0628	0.4809	0.6909	0.1439	0.5857
Sum of imported intermediate input coefficients	0.0238	0.8221	0.3442	0.0274	0.7239	0.2324
Sum of value added coefficients	0.2655	0.1151	0.1749	0.2817	0.1322	0.1818

Here *D*---production for domestic use, *P*---production for processing export, and *N*---production for non-processing exports and domestic use of FIEs.



➤ **Ordinary production for domestic (i.e. Chinese) consumers:**

- ❖ depends on domestic intermediates
- ❖ depends little on imports

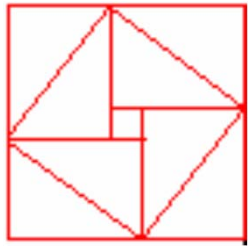
In 2002 China's IO table, the share of output is production for domestic use **82%**,
processing export 5%,
non-processing export 13%

➤ **Processing trade**

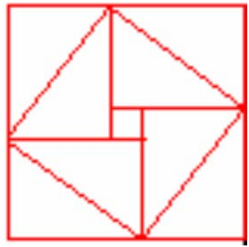
- ❖ depends very much on imports
- ❖ depends little on domestically produced goods

➤ **Input-output tables reflect the “average” production structure**

- ❖ processing trade **50%** of exports, but a minor share of production
- ❖ production related to processing trade receives a small weight in the “average” production

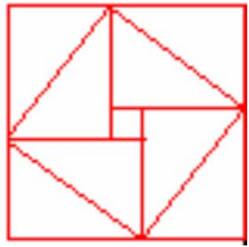


-
- **given the importance of China's processing trade, one would expect: China has much VS**
 - **Results: not much VS is measured for China**
 - **Problem??**
 - ❖ **theory is wrong?**
 - ❖ **VS measure is wrong?**
 - ❖ **data are wrong?**



Solution: A new model capturing processing trade

- **China's non-competitive extended input-output tables capturing processing trade (abbreviated as 'special table' in the following text)**
 - ❖ **In a joint project supported by the Chinese University of Hong Kong, with the collaboration of the Chinese University of Hong Kong, Hong Kong University of Science and Technology, University of California at Santa Cruz, the AMSS team compiled non-competitive input-output table of China for 2002 with 42 sectors and a non-competitive input-output table of the United States for 2002 (Lau, Chen and Yang et.al, 2006, 2007).**



A new model capturing processing trade

- **China's total production into three parts**
 - production for domestic use in China-D;**
 - processing exports production-P;**
 - non-processing exports production and other production of FIEs-N**
- **In order to highlight the sectors especially those with dominant role in processing exports, in this paper we aggregate the original China's non-competitive EIOP table to 27 sectors**

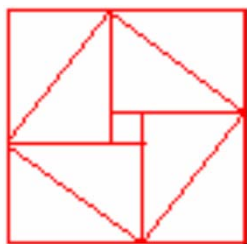


Table 2 China's non-competitive extended IO tables capturing processing trade

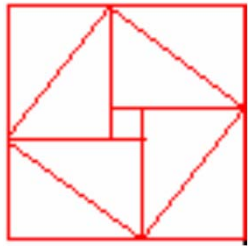
		Intermediate Use			Total	Final Use	Gross Output or Imports
		Production for Domestic Use (D)	Processing Exports(P)	Non-processing Exports and Other Production of FIEs (N)			
		1,2,..., n	1,2,..., n	1,2,..., n			
Domestically Intermediate Inputs	Production for Domestic Use (D)	X^{DD}	X^{DP}	X^{DN}		F^D	X^D
	Processing Exports(P)	0	0	0		F^P	X^P
	Non-processing Exports and Other Production of FIEs (N)	X^{ND}	X^{NP}	X^{NN}		F^N	X^N
Intermediate Inputs from Imports		X^{MD}	X^{MP}	X^{MN}		F^M	X^M
Total Intermediate Inputs							
Value-added		V^D	V^P	V^N			
Total inputs		X^D	X^P	X^N			
Employees		L^D	L^P	L^N			

The superscript **D**, **P**, **N** and **M** denotes domestic products, processing exports, non-processing exports and imports respectively.

The superscript **DD** stands for domestic products used by domestic use,

DP domestic products used by processing exports,

DN means domestic products used by non-processing exports and others, and so on.

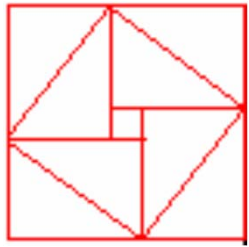


Adapting the Methodology

➤ Coefficients

$$\bar{A}^D = \begin{bmatrix} A^{DD} & A^{DP} & A^{DN} \\ 0 & 0 & 0 \\ A^{ND} & A^{NP} & A^{NN} \end{bmatrix} \quad \bar{A}^M = [A^{MD}, A^{MP}, A^{MN}]$$

$$L = \begin{bmatrix} I - A^{DD} & -A^{DP} & -A^{DN} \\ -A^{PD} & I & -A^{PN} \\ -A^{DP} & -A^{NP} & I - A^{NN} \end{bmatrix}^{-1} = \begin{bmatrix} L^{DD} & L^{DP} & L^{DN} \\ 0 & I & 0 \\ L^{DP} & L^{NP} & L^{NN} \end{bmatrix}$$



Adapting the Methodology

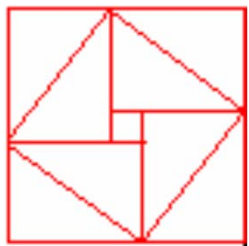
➤ **Measures for vertical specialization**

$$\text{direct: } DVS = \frac{\sum_j \lambda_j e_j}{\sum_j e_j} \quad \text{total: } TVS = \frac{\sum_j \mu_j e_j}{\sum_j e_j}$$

➤ **Measures for vertical specialization of P, N, and D**

$$DVS^P = \frac{\sum_j \lambda_j^P e_j^P}{\sum_j e_j^P} = \frac{(\lambda^P)' e^P}{u' e^P} = \frac{u' B^P e^P}{u' e^P}$$

$$DVS^N = \frac{\sum_j \lambda_j^N e_j^N}{\sum_j e_j^N} = \frac{(\lambda^N)' e^N}{u' e^N} = \frac{u' B^N e^N}{u' e^N}$$



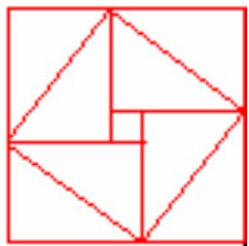
Adapting the Methodology

$$DVS^D = \frac{\sum_j \lambda_j^D f_j^D}{\sum_j f_j^D} = \frac{(\lambda^D)' f^D}{u' f^D} = \frac{u' B^D f^D}{u' f^D}$$

- **Measures the national direct vertical specialization share**

$$DVS^{NAT} = \frac{\sum_j \lambda_j^P e_j^P + \sum_j \lambda_j^N e_j^N}{\sum_j e_j^P + \sum_j e_j^N} = \frac{DVS^P \times u' e^P + DVS^N \times u' e^N}{u' e^P + u' e^N}$$

not be interpreted as a direct vertical specialization share, because the type does not export. It indicates the production's import dependence



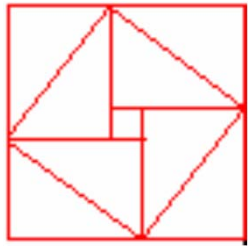
Adapting the Methodology

➤ Measures total vertical specialization share

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \begin{bmatrix} \mathbf{L}^{DD} & \mathbf{L}^{DP} & \mathbf{L}^{DN} \\ 0 & \mathbf{I} & 0 \\ \mathbf{L}^{ND} & \mathbf{L}^{NP} & \mathbf{L}^{NN} \end{bmatrix} \Rightarrow \begin{cases} (\boldsymbol{\mu}^D)' = (\boldsymbol{\lambda}^D)' \mathbf{L}^{DD} + (\boldsymbol{\lambda}^N)' \mathbf{L}^{ND} \\ (\boldsymbol{\mu}^P)' = (\boldsymbol{\lambda}^D)' \mathbf{L}^{DP} + (\boldsymbol{\lambda}^P)' + (\boldsymbol{\lambda}^N)' \mathbf{L}^{NP} \\ (\boldsymbol{\mu}^N)' = (\boldsymbol{\lambda}^D)' \mathbf{L}^{DN} + (\boldsymbol{\lambda}^N)' \mathbf{L}^{NN} \end{cases}$$

$$TVS^P = \frac{\sum_j \mu_j^P e_j^P}{\sum_j e_j^P} = \frac{(\boldsymbol{\mu}^P)' \mathbf{e}^P}{\mathbf{u}' \mathbf{e}^P} \quad TVS^N = \frac{\sum_j \mu_j^N e_j^N}{\sum_j e_j^N} = \frac{(\boldsymbol{\mu}^N)' \mathbf{e}^N}{\mathbf{u}' \mathbf{e}^N}$$

$$TVS^{NAT} = \frac{\sum_j \mu_j^P e_j^P + \sum_j \mu_j^N e_j^N}{\sum_j e_j^P + \sum_j e_j^N} = \frac{TVS^P \times \mathbf{u}' \mathbf{e}^P + TVS^N \times \mathbf{u}' \mathbf{e}^N}{\mathbf{u}' \mathbf{e}^P + \mathbf{u}' \mathbf{e}^N}$$



Results---VS share of China(2002 table)

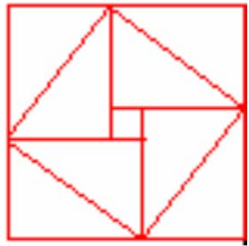
	<i>direct</i>	<i>total</i>
“ordinary” IO table	0.15	0.25
“special” IO table		
<i>P</i> (processing exports)	0.67	0.71
<i>N</i> (non-processing exports)	0.24	0.36
<i>D</i> (domestic)	0.01	0.02
<i>National</i>	0.48	0.56

Weight of ex. share

55%

45%

$$0.67*55\%+0.24*45\%=0.48$$



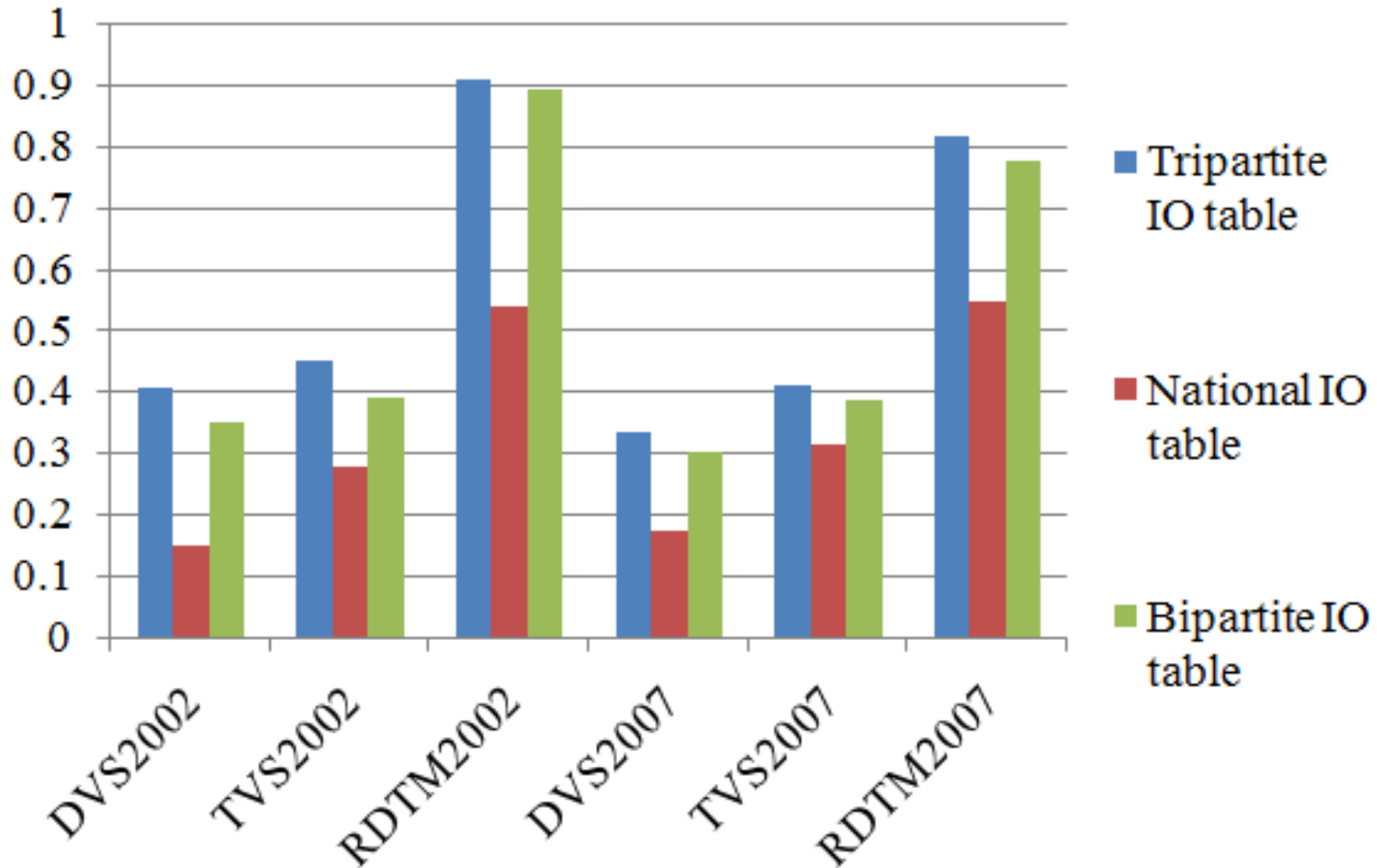
Results---VS share of China

	<i>direct</i>	<i>total</i>
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<i>National</i>	0.48	0.56
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China has a very high degree of vertical specialization

Comparing VS results



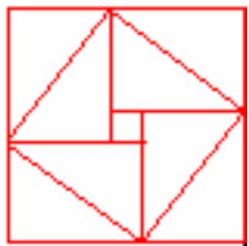
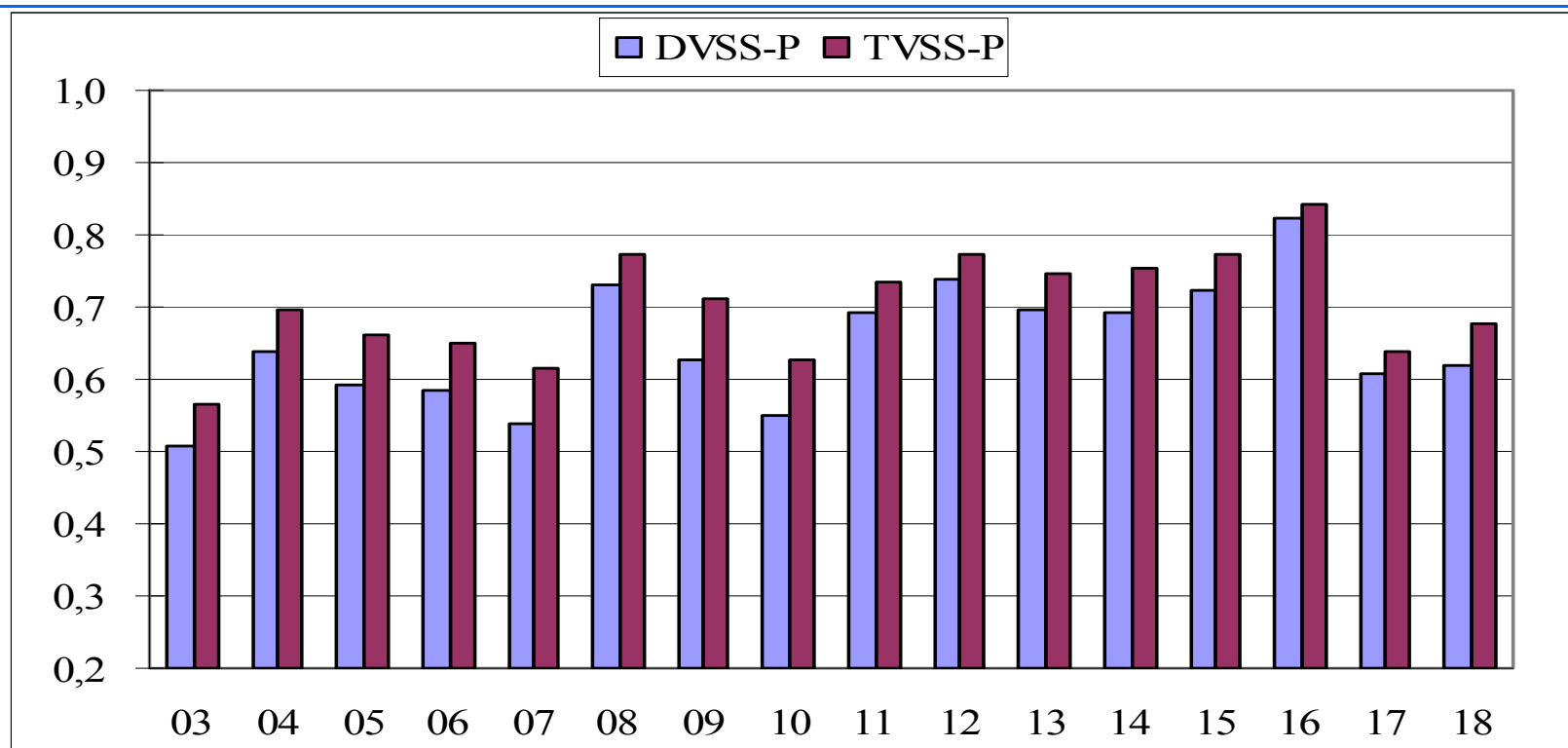


Figure 1 Direct and total VS share of processing trade by manufacturing sectors



03-Food; 04-Textile; 05-Apparel,leather and related products; 06-Wood product; 07-Paper products; 08-Petroleum processing; 09-Chemicals; 10-Non-metallic mineral products; 11-Metals smelting and pressing; 12-Metal products; 13-General and special equipment; 14-Transport equipment; 15-Electric equipment; 16-Telcommunication equipment; 17-Instruments, meters etc., equipment; 18-Other manufacturing

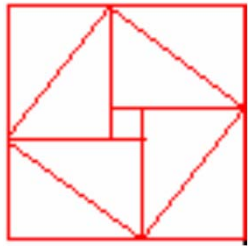
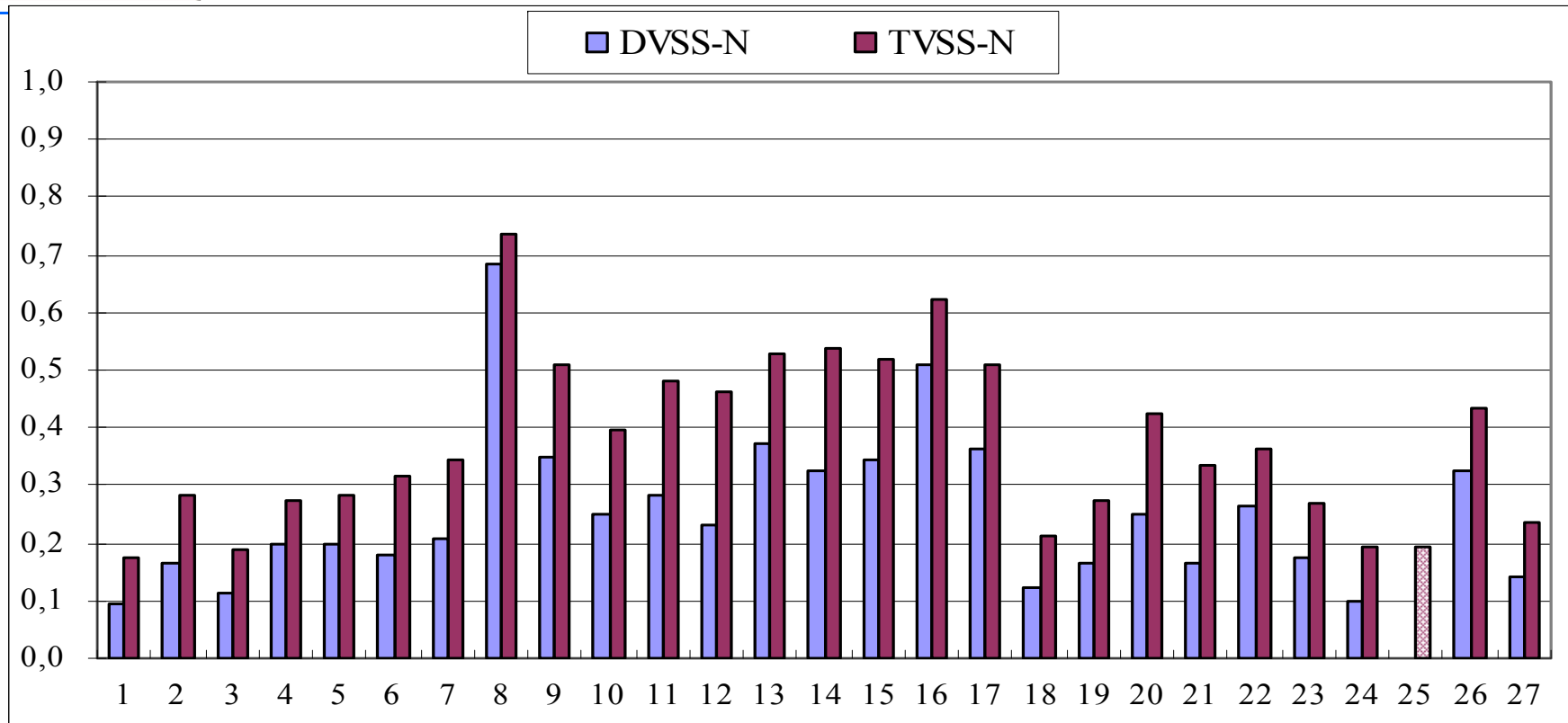
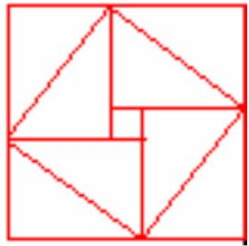


Figure 2 Direct and total VS share of non-processing trade by sectors



01-Agriculture; 02-Mining; 03-Food; 04-Textile; 05-Apparel,leather and related products; 06-Wood product; 07-Paper products; 08-Petroleum processing; 09-Chemicals; 10-Non-metallic mineral products; 11-Metals smelting and pressing; 12-Metal products; 13-General and special equipment; 14-Transport equipment; 15-Electric equipment; 16-Telcommunication equipment; 17-Instruments, meters etc., equipment; 18-Other manufacturing; 19-Electricity, water, etc; 20-Construction; 21-Transport, etc; 22-Information communication, computer service; 23-Wholesale and retail trade; 24-Catering; 25-Finance and insurance; 26-Renting service; 27-Other services;



Where the bias come from?

- The “ordinary” IO table is obtained from the new table by aggregating over the sectors D , P , and N . Thus:

$$\mathbf{M} = \mathbf{M}^D + \mathbf{M}^P + \mathbf{M}^N \quad \mathbf{x} = \mathbf{x}^D + \mathbf{x}^P + \mathbf{x}^N$$

- In an “ordinary” IO table, the national direct VS share

$$DVS = \mathbf{u}'\mathbf{B}\mathbf{e} / \mathbf{u}'\mathbf{e}$$

$$\lambda' = \mathbf{u}'\mathbf{B} = \mathbf{u}'\mathbf{M}\hat{\mathbf{x}}^{-1} = \mathbf{u}'(\mathbf{M}^D + \mathbf{M}^P + \mathbf{M}^N)(\mathbf{x}^D + \mathbf{x}^P + \mathbf{x}^N)^{-1}$$

$$= \mathbf{u}'(B^D\hat{x}^D + B^P\hat{x}^P + B^N\hat{x}^N)(x^D + x^P + x^N)^{-1}$$

$$= (\lambda^D)' \hat{\theta}^D + (\lambda^P)' \hat{\theta}^P + (\lambda^N)' \hat{\theta}^N$$

$$\hat{\theta}^J = \hat{\mathbf{x}}^J \hat{\mathbf{x}}^{-1}$$

$$J = D, P, N$$



Where the bias come from?

- In contrast, the national direct VS share in the ‘special’ table

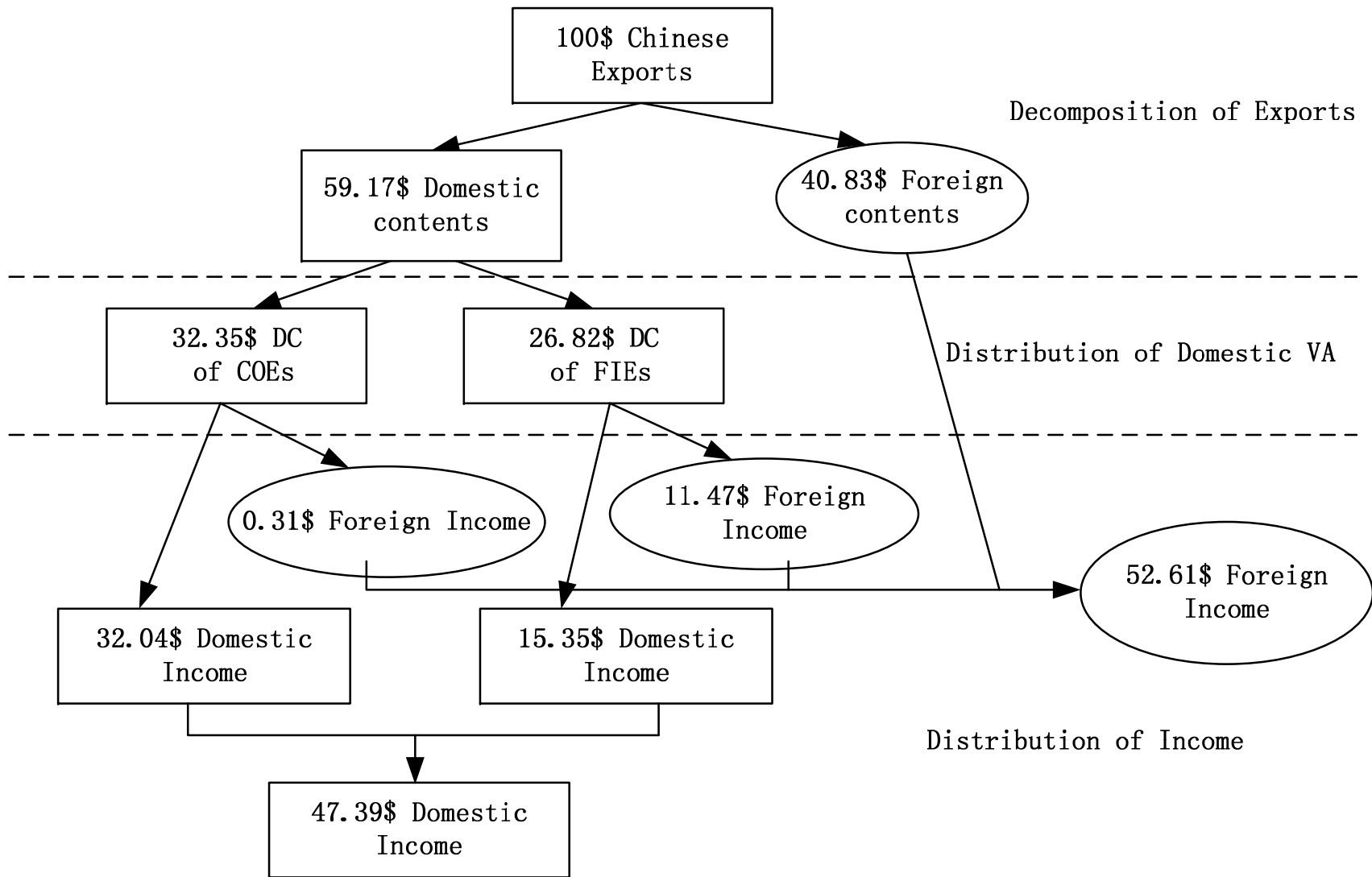
$$DVS = \lambda' \mathbf{e} / \mathbf{u}' \mathbf{e}$$

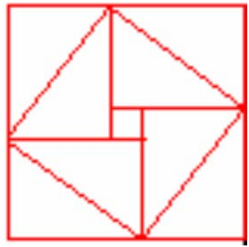
with $\lambda' = (\lambda^P)' \hat{\gamma}^P + (\lambda^N)' \hat{\gamma}^N$

where $\hat{\gamma}^J = \hat{e}^J \hat{e}^{-1}$ $\mathbf{e} = \mathbf{e}^P + \mathbf{e}^N$

$J=P, N$
the share of export

Considering Ownership of firms





Conclusion

- **Vertical specialization in China is very large**
- **The general input-output table yields biased results**
 - VS will be largely underestimated**
- **In this “special” input-output table, the typical feature of processing exports is made visible, more accurately measure VS of China**
- **This finding is expected to hold also for other countries with a lot of processing trade, e.g. Mexico, Indonesia, Vietnam**

Thanks! Your comments
and questions please.

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