Measurement of Trade in Value-Added: using Chinese Input-output Tables Capturing Processing Trade[1]

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Abstract: Total trade value is the major measurement in traditional trade statistics, Along with deepening of global integration, international fragmentation has changed the world production pattern, exported products of a certain country/region are usually produced by two or more countries/regions. Traditional trade statistics generates repeated computation, particularly for countries, like China, Mexico, Indonesia, with a high share of processing trade, repetition becomes more serious. Trade in value-added (TiVA) can be a better measurement for world trade, thus how to investigate TiVA has become an extremely important topic, especially for processing trade since it has different input structure and value added ratio compared to other production types. We will introduce a tripartite input-output model capturing processing trade based on China case. We employ this model for an empirical analysis on value-added by China's export in 2010 & 2011, on the other hand value-added by imports from China's major trading partners, based on which re-examine China's trade imbalances.
Keywords: International Trade, Processing trade, Input-output Tables, China

1. Background

Since the opening up policy in 1978, China's foreign trade has developed rapidly. Since 2009, China has become the world's largest exporter, second largest importer of goods followed by the U.S. The expansion of global trade in the past decades, however, is characterized by increasing international fragmentation, production processes are sliced into many stages that can be done in different countries. As a result, international trade is increasingly dominated by trade in parts & components. It has been argued explicitly that standard trade statistics on gross exports does not give accurate information any more about value-added by exporting country, especially for countries having to import lots of intermediate inputs to assemble exports, such as China. China's foreign trade relies highly on processing trade: exports resulting from assembly and processing of imported parts and components made up 47% of China's exports in 2010, domestic value-added (DVA) of which is relatively low. According to our estimate, the direct DVA of a US$1,000 processing exports from China is only US$166 and US$174 for 2002 and 2007, respectively (Chen, et al., 2012).

China's trade surplus with major trading partners is expected to be much lower when measured in DVA terms rather than in gross terms. According to standard trade statistics, e.g., the bilateral China-U.S. trade surplus expanded rapidly, up to US$181.3 billion in 2010. U.S. exports to China, however, have much higher DVA than China's exports to the U.S. According to Lau *et al.* (2006), China-U.S. trade surplus in terms of DVA is only US$39.6 billion in 2005, instead of US$172.3 billion in gross terms. The statistics of gross volume could be highly misleading, thus trade in value-added (TiVA) has become the focus in academia, international institutions and governmental agencies. Just as the WTO Director-General Pascal Lamy said in Geneva on 6 June 2011[2], "by focusing on gross values of exports and imports, traditional trade statistics

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[2] Available at: http://www.wto.org/english/news_e/news11_e/miwi_06jun11_e.htm

give us a distorted picture of trade imbalances between countries. …The picture would be different if we took account of how much DVA is embedded in these flows."

The rapid foreign trade growth and high share of processing trade have made China a special case in world trade. China's domestic economic benefits resulting from processing exports would have been greatly overstated if we use current approach without capturing processing exports. It is crucial to develop a framework separating productions of processing exports for China. It should be emphasized that although our framework is for China case, they hold also for other countries with substantial processing trade, such as Mexico, Brazil, Indonesia and Vietnam.

The rest of the paper is organized as follows: Section 2 introduces methodology to measure TiVA. In section 3, we present DVA results in China's gross export and export type. Section 4 describes value-added generated by bilateral trade between China and its five trading partners and trade imbalance changes. Section 5 concludes.

2. Methodology of Measuring Trade in Value-added

To measure TiVA, input-output (IO) methodology (Leontief, 1986) is widely accepted due to its ability to estimate both direct and indirect effects of exports on DVA by accounting international and inter-industry flow of global production process.

2.1 Measuring DVA in China's Exports

Processing exports constitutes about 50% of China's exports since the late 1990s. With the prevalence of processing trade, any measurement based on aggregate results combining processing exports and other production could have highly overstated China's economic benefits. Chen *et al.* (2001) firstly developed a non-competitive IO model capturing processing trade for China, named as a DP model, in which production for processing exports is differentiated from China's domestic production. The input structure of non-processing exports in China, however, is also quite different from that of production for domestic use. Lau, Chen *et al.* (2006) developed a modified version of DP model for China, where non-processing exports are further differentiated from productions of domestic use, named as a DPN model (table 1).

Table 1: China's Non-Competitive Input-Output Table Capturing Processing Trade

Output / Input		Intermediate Use			Final Use				Gross Output or Imports
		D	P	N	Consumption	Gross Capital Formation	Exports	Total Final Use	
Domestic Intermediate Inputs	D	$\mathbf{Z}^{DD}$	$\mathbf{Z}^{DP}$	$\mathbf{Z}^{DN}$	$\mathbf{F}^{DC}$	$\mathbf{F}^{DI}$	$\mathbf{0}$	$\mathbf{F}^{D}$	$\mathbf{X}^{D}$
	P	$\mathbf{0}$	$\mathbf{0}$	$\mathbf{0}$	$\mathbf{0}$	$\mathbf{0}$	$\mathbf{F}^{PE}$	$\mathbf{F}^{P}$	$\mathbf{X}^{P}$
	N	$\mathbf{Z}^{ND}$	$\mathbf{Z}^{NP}$	$\mathbf{Z}^{NN}$	$\mathbf{F}^{NC}$	$\mathbf{F}^{NI}$	$\mathbf{F}^{NE}$	$\mathbf{F}^{N}$	$\mathbf{X}^{N}$
Imported Intermediate Inputs		$\mathbf{Z}^{MD}$	$\mathbf{Z}^{MP}$	$\mathbf{Z}^{MN}$	$\mathbf{F}^{MC}$	$\mathbf{F}^{MI}$	$\mathbf{0}$	$\mathbf{F}^{M}$	$\mathbf{X}^{M}$
Value-added		$\mathbf{V}^{D}$	$\mathbf{V}^{P}$	$\mathbf{V}^{N}$					
Total inputs		$\mathbf{X}^{D'}$	$\mathbf{X}^{P'}$	$\mathbf{X}^{N'}$					

Superscript **D**, **P**, **N**, **M** denotes domestic products, processing exports, non-processing exports and imports; Superscript **DD** stands for domestic products used by domestic use, **DP** domestic products used by processing exports, **DN** domestic products used by non-processing exports and others. $\mathbf{Z}^{\mathbf{DD}}, \mathbf{Z}^{\mathbf{DP}}, \mathbf{Z}^{\mathbf{DN}}$ denote matrices of products of **D** used as intermediate inputs by **D**, **P**, **N**, respectively, and so on. Since processing exports are all exported, its intermediate demand and other final demands are all zero.

In DPN model, China's production activity is partitioned into three parts: namely, production for domestic use (D); processing exports production (P); non-processing exports production and other production of FIEs (N). We did not group "other production of FIEs" into D was due to the following considerations. Firstly, most of "other production of FIEs" ended up as indirect exports, i.e., intermediate inputs (e.g., raw material, parts) used in export production, the proportion used as intermediate inputs in domestic production sector (D) was very low. Secondly, FIEs have similar input structure with export production rather than that of domestic production.

Denote $\mathbf{Z}^D = \begin{pmatrix} \mathbf{Z}^{DD} & \mathbf{Z}^{DP} & \mathbf{Z}^{DN} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{Z}^{ND} & \mathbf{Z}^{NP} & \mathbf{Z}^{NN} \end{pmatrix}$, $\mathbf{X} = \begin{pmatrix} \mathbf{X}^D \\ \mathbf{X}^P \\ \mathbf{X}^N \end{pmatrix}$, $\mathbf{F} = \begin{pmatrix} \mathbf{F}^D \\ \mathbf{F}^P \\ \mathbf{F}^N \end{pmatrix}$, $\mathbf{E} = \begin{pmatrix} \mathbf{0} \\ \mathbf{F}^{PE} \\ \mathbf{F}^{NE} \end{pmatrix}$, $\mathbf{V} = \begin{pmatrix} \mathbf{V}^D \\ \mathbf{V}^P \\ \mathbf{V}^N \end{pmatrix}'$,

Define direct input coefficient $\mathbf{A}^D = \mathbf{Z}^D(\widehat{\mathbf{X}})^{-1}$, where $\widehat{\mathbf{X}}$ is diagonal matrix of output value $\mathbf{X}$, row vector of value-added ratio is $\mathbf{A}_\mathrm{V} = \mathbf{V}(\widehat{\mathbf{X}})^{-1}$. We then have:

$$\mathbf{A}^D\mathbf{X} + \mathbf{F} = \mathbf{X} \quad \text{i.e.} \quad \mathbf{X} = (\mathbf{I} - \mathbf{A}^D)^{-1}\mathbf{F} \tag{1}$$

From formula (1), we can obtained the output generated by export (E):

$$\mathbf{X}^E = (\mathbf{I} - \mathbf{A}^D)^{-1}\mathbf{E} \tag{2}$$

Further, value-added generated by export can be calculated, i.e.

$$\mathbf{V}^E = \mathbf{A}_\mathrm{V}\mathbf{X}^E = \mathbf{A}_\mathrm{V}(\mathbf{I} - \mathbf{A}^D)^{-1}\mathbf{E} \tag{3}$$

For value-added generated by processing export & non-processing export, we have:

$$\mathbf{V}^{PE} = \mathbf{A}_\mathrm{V}(\mathbf{I} - \mathbf{A}^D)^{-1}\mathbf{E}^P; \quad \mathbf{V}^{NE} = \mathbf{A}_\mathrm{V}(\mathbf{I} - \mathbf{A}^D)^{-1}\mathbf{E}^N \tag{4}$$

This methodology was subsequently adopted, directly or indirectly, with variations, by other researchers working on similar and related topics (Dean, et al., 2011; Koopman, et al., 2012). In this paper, we employed the model by Lau, Chen *et al.* (2006) and compiled corresponding IO tables to measure China's DVA of exports for 2010 & 2011. We compiled an updated non-competitive IO table capturing processing trade of China for 2010, measured DVA of China's exports by sector, by HS classification (at 2-digit level) and by exports destination[3]. 2010 IO table is updated from a survey-based IO table of 2007[4], with latest information from China's National Bureau of Statistics (2010 National IO table, concordance table between customs data & IO sector, manufacturing production data & circulation costs in 2010), General Administration of Customs (merchandise trade data by trading partners, by sub-type, 2010 & 2011), Ministry of Commerce (service production data for foreign enterprises in 2010), and the State Administration of Foreign Exchange (e.g. service trade data).

2.2 Measuring DVA in China's imports

Corresponding to value-added generated by a country/region's exports, it is also necessary to measure value added generated by its imports in order to measure trade imbalance in terms of TiVA. Different from exports, value-added by imports is practically embodied as the DVA of its import country/region of origin. We have to employ IO statistics and exports data of trading partners when measuring DVA of China's import. Take DVA measurement of China's import from the U.S. for example, we synthesized the IO table from "Make Table" and "Use Table" at the summary level for 2010, released on the website of Bureau of Economic Analysis, U.S. Department of Commerce[5]. Regarding trade statistics, however, there is sometime huge discrepancy between China's import data from General Administration of Customs of China (GACC) and export data to China released by trading partners. Again China-US trade data for example, Fung *et al* (2006) have a detailed discussion on the large differences between the official U.S and China data on trade balances between the two countries. According to newly released data, in 2012, according to U.S. Government data, the U. S. ran a merchandise trade deficit of US$315.1 billion with China. However, according to GACC, China's surplus with the U. S. was US$231.1 billion.

In order to keep consistent, we conform to the same dataset from GACC, i.e. by substituting China's import data for export data of trading partners to measure DVA of China imports. We need several extensions of GACC import data, which will not be explained in this paper. The extensions include: transforming from CIF to FOB prices;

[3] In this paper, we focus on the value added by gross exports by sector as well as by destination. The results for HS 2-digit level are not included, but are available upon request from the authors.

[4] The 2007 table was jointly compiled by National Bureau of Statistics and Academy of Mathematics and Systems Science (AMSS) of the Chinese Academy of Sciences.

[5] Available at: http://www.bea.gov/industry/io_annual.htm

concordance table between GACC data and IO data of trading partners; conversion of FOB price to producer's price/basic price in IO tables of trading partners.

3. China’s DVA contents of exports

The results are listed in table 2. From table 2, we have the following observations:

(1) DVA of China’s exports is relatively low. US$1000 of China’s exports would generate a total DVA of US$615 in 2010. China’s gross exports of goods and services are US$1749 billion in 2010 [6], 29.5% of China’s GDP. DVA of such exports, however, is measured to be only US$1076 billion, 18.1% of China’s GDP.

(2) DVA of China’s processing exports is particularly low. Processing exports involve domestic firms more imported materials for assembling or processing, they have very limited DVA contents. US$1000 of China’s processing exports in 2010 only generates US$387 of total DVA, less than half of that induced by non-processing exports. Processing exports account for as high as 46.9% of China’s total exports in 2010, however, its contribution in terms of DVA to total exports is only 26.6%.

(3) DVA of China’s exports increased slightly over time. US$1000 of China’s exports in 2011 generates US$618 of total DVA, slightly higher than that of 2010. It should be noted that both measurements of 2010 & 2011 are based on the same IO table, thus the increase is mainly due to the decline of processing exports share.

Table 2. DVA of China’s Exports (2010 and 2011)

	DVA of US$ 1000 of China exports (in US$)		DVA of China total exports （in billion US$）	
	2010	**2011**	**2010**	**2011**
Exports*	615	618	1076	1286
-processing exports	387	384	287	321
-non-processing exports	781	776	789	965

Note：Exports in table 2 include exports of both goods and services.

(4) The highest DVA per US$1000 exports is found from Agriculture industry, followed by Services & the Secondary Industry. The results show that US$1000 exports of agriculture would generate US$925 DVA in 2010, and US$885 DVA for services and US$564 DVA for the secondary industry. In fact, agriculture and services generally have lower material inputs and thus enjoy higher value added ratios than manufacturing. Moreover, the shares of processing exports of agriculture and services are much lower than that of manufacturing. As for results by sector, most of mining sectors have DVA more than US$800, e.g., mining and washing of coal (US$856). Traditional labor-intensive and skill-intensive sectors generally have DVA between US$700-800, e.g., textile (US$786). High-tech sectors have DVA lower than US$550, e.g., electric machinery & equipment(US$523), transport equipment (US$521). A further exploration shows that high-tech sectors are often accompanied by high shares of processing exports (50% or more), for which DVA is relatively low.

4. DVA in China’s Trade by Trading Partners and Trade Imbalances in TiVA

4.1 China’s DVA contents of exports to trading partners

Based on 2010 DPN IO table of China, we estimate DVA of China’s exports to the above trading partners (U.S., EU27, ASEAN, Japan, South Korea and India). Figure 1 shows how the DVA of US$1000 exports vary with different trade partners in 2010(the results for 2011 is similar to that of 2010, though exact numbers are slightly different). There are several observations:

(1) The highest DVA by China’s US$ 1000 exports of goods is that to India and the lowest is South Korea. China’s exports of goods to EU, India and ASEAN show a similar trajectory, with DVA content higher than that of total exports. The exports of

[6] Source: exports of goods are from General Administration of Customs of China, exports of services are from State Administration of Foreign Exchange.

goods to Japan, the U.S., Korea have DVA content less than that of total exports. DVA of exports to the above trading partners are all slightly rising over time (2010-2011). In 2010, China's export of goods to the U.S is only US$159.5 billion in terms of DVA, much less than the Customs record of US$283.3 billion. China-U.S. bilateral trade surplus has been overstated, when consider economic benefits (i.e. DVA) of exports.

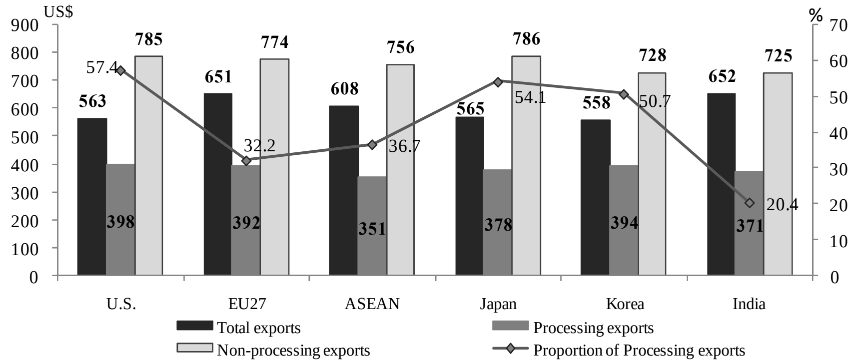

Figure 1. Total DVA of China's US$1000 exports of goods to trading partners (2010)

(2) The fact that DVA of US$ 1000 processing exports is much lower than the non-processing exports is robust with different trading partners. More specifically, in China's exports of goods, DVA induced by US$1000 processing exports to the U.S., EU, ASEAN, Japan, South Korea and India are only 50.7%, 50.6%, 46.4%, 48.1%, 54.1% and 51.2% of their corresponding DVA induced by non-processing exports.

(3) Differences in DVA of China' US$1000 exports of goods to various trading partners are closely related to their corresponding shares of processing exports. As shown in figures 1, up to 50% of China's exports of goods to the U.S., Japan and South Korea are processing exports, for which the exports of goods to these areas have generally lower DVA. In contrast, China's exports of goods to EU, ASEAN and India often have higher DVA, where their shares of processing exports are lower than 35%.

4.2 DVA for Trading Partners induced by China's Imports and Trade Imbalances

Based on IO tables of trading partners and China imports data, we estimate DVA for trading partners generated by US$1000 of China's imports for 2010, as shown in table 3, and further estimate the trade imbalances in TiVA (table 4). Tables 3 & 4 shows:

Table 3. DVA for Trading Partners by US$1000 of China's imports (US$)

	U.S.	EU27	Japan	South Korea	India
2010	860	807	805	491	807

Note: We only include results with five trading partners, data for ASEAN is still in processing.

Table 4. Trade Imbalances: comparison between total value & TiVA (billion US$; %)

		U.S.	EU27	Japan	South Korea	India
2010	Difference in total value(1)	181.2	142.8	-55.7	-69.6	20.1
	Difference in value-added(2)	79.4	80.6	-68.8	-29.5	10.4
	Change ratio [(2)-(1)]/(1)*100	-56.2	-43.6	23.5	-57.6	-48.1

(1) The highest DVA generated by China's US$1000 imports of goods is for the U.S. and the lowest is for South Korea, at US$860 and US$491 in 2010, respectively. DVA for EU, Japan and India is very close, at about US$800. A common ground is the DVA generated by China's imports for the U.S., EU, Japan and India is much higher than the DVA of China's export to the above four partners.

(2) Due to the differences among DVA generated by China's imports for trading partners, the rankings of China's trading partners change in terms of TiVA. For example, South Korea is China's third largest importing country in terms of total imports value, while decreases to the fourth when measuring in value-added.

(3) When looking at the trade imbalances in value-added, China's trade surplus with

the U.S, EU and India, and China's trade deficit with South Korea go down by 56.2%, 43.6%, 48.1% and 57.6% in 2010, respectively. On the contrary, China-Japan trade deficit goes up by 23.5% in the same year.

5. Conclusions

This research measured DVA contents of China's exports over time by sector, HS classification (at 2-digit level) and exports destination. The results show that DVA per US$1000 of China's exports is still low, especially the DVA of US$1000 processing exports is less than half of that by non-processing exports. Therefore, traditional trade statistics in gross volume have heavily overstated China's economic benefits from trade, as well as China's trade surplus. Although China's increased involvement in international production fragmentation is largely due to the performance of processing exports, such exports actually have very limited contributions to GDP growth. It should be encouraged to upgrade China's position in global value chain by improving the competitiveness of exports in the future decades. The results by sector show that exports of traditional labor-intensive products such as agriculture, services, textile, furniture and services have generally higher DVA than that of technology-intensive products such as electronic and machinery. It is suggested that China should not only maintain the share of exports in traditional labor-intensive products, but also to increase share of exports in services and improve the TiVA in high-tech products.

When investigating value-added generated by China's trade with major trading partners, we find that on one hand, China's exports to EU, India and ASEAN have relatively high DVA contents while the exports to U.S., Japan and South Korea have relative low DVA contents, mainly due to differences of shares in processing exports to different areas. On the other hand, DVA generated by China's imports for the U.S., EU, Japan and India is much higher than the DVA of China's export to the above four partners. Therefore, when measuring in TiVA, we see a sharp decline in China's trade surplus with the U.S., EU and India, and increase in China's trade deficit with Japan.

References

Chen X.K., Cheng L. K., Fung K. C., Lau L. J., 2001, The Estimation of Domestic Value-Added and Employment Induced by Exports: An Application to Chinese Exports to the United States," Working Paper, Stanford University, 94305, June.

Chen, X.K., Cheng L. K., Fung K. C., Lau L. J., Sung Y.W., Zhu K.F, Yang C.H., Pei J.S., Duan Y.W., 2012, Domestic value added and employment generated by Chinese exports: A quantitative estimation, *China Economic Review*, 23: 850–864

Hummels, David, Jun Ishii and Kei-Mu Yi, 2001, The Nature and Growth of Vertical Specialization in World Trade, *Journal of International Economics* 54:75-96.

Dean J. M., Fung K. C., Wang Z., 2011, Measuring Vertical Specialization: the Case of China, Review of International Economics, Volume 19, Issue 4, pages 609–625

Koopman, R., Wang, Z. Wei, S.-J., 2012, Estimating domestic content in exports when processing trade is pervasive. *Journal of Development Economics*, 99, 178-189 (2008 NBER Working Paper 14109, http://www.nber.org/papers/w14109)

Lau, L. J., Cheng L. K., Fung K. C., Pei J., Sung Y.W., Tang Z., Xiong Y., Yang C.H, and Zhu K.F., 2006, "Estimates of U.S.-China Trade Balances in Terms of Domestic Value-Added," *Working Paper No. 295*, Stanford Center for International Development, Stanford University.

Leontief, W.W., 1986, Input-output Economics, 2nd edition, Oxford University Press

Fung K. C., Lau, L. J.,Xiong Y., 2006, Adjusted Estimates of U.S-China Bilateral Trade Balances: An Update, *Pacific Economic Review*, Vol. 11, No. 3, pp. 299-314.

Lau,L. J., Chen X.K., Yang C.H, Cheng L. K., Fung K.C., Sung Y.W., Zhu K.F., Pei J.S. and Tang Z.P., 2010, Input-occupancy-output Models of the Non-competitive Type and their Application – an Examination of China-US Trade Surplus, *Social Sciences in China*, Vol, XXXI, No.1, pp.35-54 (The Chinese version of this paper was published in *Social Sciences in China* in 2007: No. 5, 91-103).