Value added trade and structure of high-technology exports in China

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Keywords: Technology, Production networks, Value added trade

JEL classification: C67, F15, O39

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Abstract

This study focuses on the technological intensity of China's exports. It first introduces the method of decomposing gross exports by using the Asian international input–output tables. The empirical results indicate that the technological intensity of Chinese exports has been significantly overestimated because of its high dependency on import content, especially in high-technology exports, an area highly dominated by the electronic and electrical equipment sector. Furthermore, a significant portion of the import content of China's high-technology exports comes from services and high-technology manufacturers in neighboring economies, such as Japan, South Korea, and Taiwan.

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1 Introduction

The technological level of industry in a country is reflected in the structure of trade, and especially of exports. It is obvious that as the technological level of industry goes up, the technology intensity of exports also rises, and simultaneously more sophisticated products are exported from the country, so that its export structure may approach that of more advanced economies.

The above relationship, however, becomes less straightforward when we consider the reverse causality; that is, whether a large proportion of high-technology exports is accompanied by strong technological capabilities. Deciding this has become increasingly difficult, as many developing countries are engaged in vertical fragmentation of production (Lall, 2000; Srholec, 2006). For example, if a highly export-oriented economy, such as China, acts as a part of production networks organized by multinational enterprises and is engaged in assembling high-technology products that heavily depend on imported inputs, the technology intensity of exports that is measured by trade statistics will be raised accordingly. But does this increased statistic reflect an actual increase in the technological capabilities of the exporting country?

In recent years, many studies have been conducted to estimate the technological intensity of China's exports. The above observation, however, raises a serious concern about how best to measure technological intensity of exports. Trade statistics, which have been used to measure this, may not be appropriate in an environment of rapidly progressing vertical fragmentation.

In this study, an alternative approach will be presented. Instead of export values, the domestic content of exports will be used as a measure of the technological intensity of exports. Note that, in estimating the domestic content of exports, value from foreign content is removed from total export values, so that the value added by only domestic factors of production is captured by the measure. The Asian input–output (AIO) tables will be used to estimate the domestic content of exports. The AIO tables cover inter-industry transactions within nine East Asian economies and the United States; other economies are treated exogenously in aggregate as the "rest of the world" (ROW).[1]

Value added exports is also used as an alternative measure of the technological intensity of exports. Value added exports indicate the flow of value added between the source and destination countries and are associated with trade flow. Such exports are conceptually distinct from the domestic content of exports: The relations among the three measures (gross exports, domestic content of exports, and value added exports) will be shown in a systematic manner with particular reference to the AIO tables.

Indices of vertical specialization, originally developed by Hummels et al. (2001), will be applied to the AIO tables. These indices will provide valuable information on how various economies are involved in East Asian production networks and how they procure the intermediate inputs used to produce exports.

This study focuses on the technological intensity of China's exports, but it also examines inter-industry linkages with neighboring economies, such as Japan, South Korea, and Taiwan, which are major suppliers of intermediate inputs for China's high-technology exports. Because Chinese industries, and particularly its high-technology industries, have forged a close and complementary relationship with neighboring countries, it is crucially important to examine the issue from a regional perspective. The study also compares the technology intensity of China's exports with

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[1] The AIO tables cover China, Japan, South Korea, Taiwan, Singapore, Malaysia, the Philippines, Thailand, Indonesia, and the United States.

those of neighboring countries.

The paper is organized as follows. Section 2 reviews previous empirical works on the export structure of China. Section 3 presents the methods of analysis. Section 4 discusses the obtained results. Section 5 provides a conclusion.

2 Export structure of China

In this section, we first look at major characteristics of China's involvement in vertical production networks. After that, previous studies on the sophistication of China's exports are discussed.

2.1 Triangular trade structure

China's rapid economic growth is closely related to its involvement in East Asian production networks. For example, it is well-known that China emerged (at the expense of many Southeast Asian economies) as a final manufacturing assembler in East Asia after its accession to the WTO in 2001. China's role is most aptly understood from a view of the triangular trade, whereby China imports intermediate inputs from neighboring East Asian economies, assembles them, and then exports final products to the US and EU markets (Kuroiwa and Kuwamori, 2011). A triangular trade structure is especially prominent in the electrical appliances and office and telecommunication equipment sectors (Haddad, 2007; Tong and Zheng, 2008).

2.2 Sophistication of exports

Another important characteristic of China is its rapid sophistication of the export structure. Sophistication of exports can be measured in a variety of ways. For example, Rodrik (2006) and Hausmann et al. (2007) estimate the degree of export sophistication by using PRODY and EXPY. PRODY is a weighted sum of the per capita GDP of the countries exporting a given product and, therefore, represents the income level associated with each of these products; EXPY is the weighted sum of PRODY, where the weight is given by the share of each product in the country's total exports. Therefore, EXPY represents the income level associated with the country's overall export bundle. As a consequence, Rodrik (2006) shows that China has exported a wide range of highly sophisticated products, and its export bundle is similar to that of a country with a per-capita income three times higher than China's (Rodrik, 2006). Moreover, an empirical study conducted by Jarreau and Poncet (2009) reveals that the sophistication of exports has positively influenced the export and growth performances of Chinese provinces.

An alternative approach to measure export sophistication is to use a measure of export similarity developed by Finger and Kreinin (1979). The export similarity index (ESI) is defined by the formula, $ESI_{\mathrm{tcd}} = \sum_{\mathrm{p}} \min(S_{\mathrm{tpc}}, S_{\mathrm{tpd}})$, where S_{tpc} is the share of country *c*'s exports in manufacturing product p during year t. The ESI is a bilateral measure that takes values between 0 and 1: $ESI_{\mathrm{tcd}} = 0$ if countries c and d have no products in common during year t and $ESI_{\mathrm{tcd}} = 1$ if their exports are distributed identically across products. Using the ESI, Schott (2006) examines the relative sophistication of China's exports to the United States and shows that China's export overlap with more developed countries (in that study, OECD countries) has increased dramatically over time, jumping from a rank of 21 among non-OECD U.S. trading partners in 1972 to a rank of 3 in 2001, just behind Mexico and South Korea and ahead of Taiwan.

2.3 Technological intensity of exports

Another group of scholars, however, has criticized the rather optimistic conclusion regarding the upgrading of export composition in developing countries such as China. Lall (2000), for example, investigates the technology structure and performance of developing countries' manufactured exports, and notes that a significant part of the high-technology industry growth in developing countries might be "something of a statistical illusion," because the countries are specializing in labor-intensive processes within technology-intensive activities. Srholec (2007), in contrast, argues that specialization in high-technology exports can be a mere reflection of high-technology component imports: his econometric analysis reveals that although domestic technological capabilities are associated with export performance in electronics—which occupies a dominant share of high-technology exports in developing countries—it is the propensity to import electronics components that accounts for the largest portion of cross-country differences in specialization in electronics exports. In a similar vein, Amiti and Freund (2010) examine the skill content of manufacturing exports in China. They find that although there has been a significant increase in the skill content of China's total manufacturing exports, it is mainly due to an increase in imported inputs used for processing trade.

The above discussions reveal the necessity to separate the influences of imported inputs from those of domestic factor inputs. The next section introduces a method of input–output analysis that meets this requirement in a systematic and consistent manner.

3 Method of analysis

In this section, a method of input–output analysis is presented for analyzing the technological structure of exports. First, gross exports are decomposed into several elements, with a focus on the relations among gross exports, value added exports, and domestic content of exports. Then, measures of the technological intensity of exports are introduced, with reference to the above three export measures. Finally, the indices of vertical specialization are presented.

3.1 Decomposition of gross exports in the AIO tables

Input–output analysis has been used often to estimate induced outputs for exogenously given final demand. In the analysis of domestic content of exports, induced domestic value added (rather than output) is estimated for a given level of exports. Recently, Koopman et al. (2012) developed a method of decomposition of gross exports for the global inter-country input–output (ICIO) tables. This paper, in contrast, attempts to apply a similar method to input–output tables of a different format, the AIO tables. We note that a major difference between the global ICIO tables and the AIO tables lies in their treatments of the "imports from the ROW" matrices and the "exports to the ROW" vectors: these two trade-related transactions are treated endogenously in the ICIO tables and exogenously in the AIO tables.

From the equality of demand and output supply in the AIO tables, it holds that

$$x^r = A^{r1}x^1 + A^{r2}x^2 \dots A^{rG}x^G + f^{r1} + f^{r2} \dots + f^{rG} + r^r \text{ for } r = 1,2,\dots G \quad (1)$$

where x^r is country r's $n \times 1$ vector of outputs (n and G are, respectively, the numbers of industrial sectors and of endogenous countries in the AIO tables); $A^{rs}x^{s}$ is an $n \times 1$ vector that indicates the flows of intermediate inputs provided by country r to country s (A^{rs} is an $n \times n$ input coefficient matrix) ; f^{rs} is an $n \times 1$ vector of final goods provided by country r and consumed by country s; and r^{r} is country r's $n \times 1$ vector of exports to the ROW. Note that, different than the ICIO tables, the AIO tables cover transactions (both intermediate inputs and final goods) among only nine Asian countries and the United States (see footnote 1), so that Country r's exports to other countries or regions are summed up and included in a single vector of exports to the ROW, r^{r}.

Next, Eq. (1) can be rewritten in a matrix form as

$$\begin{bmatrix} x^{1} \\ \vdots \\ x^{G} \end{bmatrix} = \begin{bmatrix} A^{11} & \cdots & A^{1G} \\ \vdots & \ddots & \vdots \\ A^{G1} & \cdots & A^{GG} \end{bmatrix} \begin{bmatrix} x^{1} \\ \vdots \\ x^{G} \end{bmatrix} + \begin{bmatrix} f^{11} + f^{12} \ldots + f^{1G} + r^{1} \\ \vdots \\ f^{G1} + f^{G2} \ldots + f^{GG} + r^{G} \end{bmatrix}. \qquad (2)$$

Solving Equation (2) for x yields

$$\begin{bmatrix} x^{1} \\ \vdots \\ x^{G} \end{bmatrix} = \begin{bmatrix} I - A^{11} & \cdots & -A^{1G} \\ \vdots & \ddots & \vdots \\ -A^{G1} & \cdots & I - A^{GG} \end{bmatrix}^{-1} \begin{bmatrix} f^{11} + f^{12} \ldots + f^{1G} + r^{1} \\ \vdots \\ f^{G1} + f^{G2} \ldots + f^{GG} + r^{G} \end{bmatrix}$$

$$= \begin{bmatrix} B^{11} & \cdots & B^{1G} \\ \vdots & \ddots & \vdots \\ B^{G1} & \cdots & B^{GG} \end{bmatrix} \begin{bmatrix} \sum_{s=1}^{G} f^{1s} + r^{1} \\ \vdots \\ \sum_{s=1}^{G} f^{Gs} + r^{G} \end{bmatrix}, \quad (3)$$

where B^{rs} is an $n \times n$ submatrix of the Leontief inverse matrix. Then, the value added in country r (i.e., va^{r}), which is induced by the final demand vector, is obtained by pre-multiplying Eq. (3) by a value added coefficient matrix.

$$\begin{bmatrix} va^1 \\ \vdots \\ va^G \end{bmatrix} = \begin{bmatrix} \hat{V}^1 & \cdots & O \\ \vdots & \ddots & \vdots \\ O & \cdots & \hat{V}^G \end{bmatrix} \begin{bmatrix} B^{11} & \cdots & B^{1G} \\ \vdots & \ddots & \vdots \\ B^{G1} & \cdots & B^{GG} \end{bmatrix} \begin{bmatrix} \sum_{s=1}^{G} f^{1s} + r^1 \\ \vdots \\ \sum_{s=1}^{G} f^{Gs} + r^G \end{bmatrix}$$

$$= \begin{bmatrix} \sum_{r=1}^{G} \hat{V}^1 B^{1r} (\sum_{s=1}^{G} f^{rs} + r^r) \\ \vdots \\ \sum_{r=1}^{G} \hat{V}^G B^{Gr} (\sum_{s=1}^{G} f^{rs} + r^r) \end{bmatrix}, \qquad (4)$$

where $\hat{V}^r$ is country r's $n \times n$ diagonal matrix of value added coefficients (value added coefficients are ratios of value added relative to total output). From Eq. (4), total value added exports from country s to country r can then be calculated as

$$vt^{sr} = u' \hat{V}^s \sum_{g=1}^{G} B^{sg} f^{gr}$$

$$= v^{s\prime} \sum_{g=1}^{G} B^{sg} f^{gr}, \qquad (5)$$

where vt^{sr}represents the value added generated in source country s but absorbed (or consumed) as final products in destination country r, and u' is a 1 x n row vector whose entries are all 1. Note that Eq. (5) is conceptually equivalent to the "value added exports" defined by Johnson and Noguera (2012). By summing over the destination countries, country s's value added exports to the world are given by

$$vt^{s*} = u' \hat{V}^s \sum_{g=1}^{G} B^{sg} (\sum_{r \neq s}^{G} f^{gr} + r^g)$$

$$= v^{s\prime} \sum_{g=1}^{G} B^{sg} (\sum_{r \neq s}^{G} f^{gr} + r^g). \qquad (6)$$

Note that, unlike in the analysis in Koopman et al. (2012), Eq. (6) includes r^g, which indicates country g's value added exports to the ROW.

From the relations among the value added coefficient matrix, the imports from the ROW matrix, and the Leontief inverse matrix, it holds that

$$\sum_{r=1}^{G} u'(\hat{V}^{r} + \hat{M}^{r})B^{rs} = \sum_{r=1}^{G}(v^{r\,\prime} + m^{r\prime})B^{rs} = u', \qquad (7)$$ [2]

where $\hat{M}^{r}$ is an import coefficient matrix that indicates the flows of intermediate inputs provided by the ROW to country r. On the other hand, country s's exports to the world by industrial sector can be calculated as

$$e^{s*} = \sum_{r \neq s}^{G} e^{sr} = \sum_{r \neq s}^{G}(A^{sr}x^{r} + f^{sr}) + r^{s}. \qquad (8)$$

Note that $A^{sr}x^{r}$ and f^{sr}respectively represent exports of intermediate inputs and final goods from country s to country r. Substituting Eq. (7) into Eq. (8), country s's gross exports can be calculated as

$$u'e^{s*} = \sum_{r=1}^{G}(v^{r\,\prime} + m^{r\prime})B^{rs}e^{s*}$$

$$= (v^{s\prime} + m^{s\prime})B^{ss}e^{s*} + (v^{r\prime} + m^{r\prime})\sum_{r \neq s}^{G} B^{rs}e^{s*}. \qquad (9)$$

Rearranging Eq. (6) and Eq. (8), the first term of Eq. (9) can be expressed as

[2] Eq. (7) indicates how much value added and imports from the ROW are induced when one unit of final demand is given to all sectors in country s. In this case, since final demand (exogenously given) induces the same amount of either value added in endogenous countries or imports from the ROW, the sum of value added and imports from the ROW always equals one unit, seen directly in Eq. (7).

$(v^{s\prime} + m^{s\prime})B^{ss}e^{s*} = \ vt^{s*} + m^{s\prime}\sum_{g=1}^{G} B^{sg}\,(\sum_{r\neq s}^{G} f^{gr} + r^g) + (v^{s\prime} + m^{s\prime})B^{ss}[\sum_{r\neq s}^{G}(A^{sr}\,X^r + f^{sr}) + r^s] - (v^{s\prime} + m^{s\prime})\ \sum_{g=1}^{G} B^{sg}\,(\sum_{r\neq s}^{G} f^{gr} + r^g)$. (10)

Since $x^s = \sum_{r=1}^{G}(A^{sr}\,x^r + f^{sr}) +\ r^s$ and simultaneously $x^s = \sum_{g=1}^{G} B^{sg}\,(\sum_{r=1}^{G} f^{gr} + r^g)$ (see Eqs. (2) and (3)), the third and fourth terms of Eq. (10) can be rewritten as

$$z^s = (v^{s\prime} + m^{s\prime})[B^{ss}(x^s - A^{ss}x^s - f^{ss}) - (x^s - \sum_{g=1}^{G} B^{sg}\, f^{gs})]$$

$$= (v^{s\prime} + m^{s\prime})\{[B^{ss}(I - A^{ss}) - I]x^s + \left(\sum_{g=1}^{G} B^{sg}\, f^{gs} - B^{ss}f^{ss}\right)\}. \quad (11)$$

Then, substituting $B^{ss}(I - A^{ss}) - I$ in Eq. (11) with $\sum_{r\neq s}^{G} B^{sr}A^{rs}$,[3] we get

$$z^s = (v^{s\prime} + m^{s\prime})[\sum_{r\neq s}^{G} B^{sr}\,(A^{rs}x^s + f^{rs})]. \qquad (12)$$

Inserting Eq. (12) into Eq. (9) and Eq. (10) yields

$$u'e^{s*} = \ vt^{s*} + m^{s\prime}\sum_{g=1}^{G} B^{sg}\,(\sum_{r\neq s}^{G} f^{gr} + r^g)\ + (v^{s\prime} + m^{s\prime})[\sum_{r\neq s}^{G} B^{sr}\,(A^{rs}x^s + f^{rs})]$$
$$+ (v^{r\prime} +\ m^{r\prime})\sum_{r\neq s}^{G} B^{rs}e^{s*}$$
$$= vt^{s*} + v^{s\prime}(\sum_{r\neq s}^{G} B^{sr}\, e^{rs}) +\ v^{r\prime}\sum_{r\neq s}^{G} B^{rs}e^{s*}$$
$$+ m^{s\prime}\sum_{g=1}^{G} B^{sg}\,(\sum_{r\neq s}^{G} f^{gr} + r^g) + m^{s\prime}(\sum_{r\neq s}^{G} B^{sr}\, e^{rs}) + m^{r\prime}\sum_{r\neq s}^{G} B^{rs}e^{s*}. \qquad (13)$$

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[3] From Eq. (3), it holds that

$$\begin{bmatrix} B^{11} & \cdots & B^{1G} \\ \vdots & \ddots & \vdots \\ B^{G1} & \cdots & B^{GG} \end{bmatrix}\begin{bmatrix} I - A^{11} & \cdots & -A^{1G} \\ \vdots & \ddots & \vdots \\ -A^{G1} & \cdots & I - A^{GG} \end{bmatrix} = \begin{bmatrix} I & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & I \end{bmatrix}.$$

Thus, we obtain $B^{ss}(I - A^{ss}) - I = \sum_{r\neq s}^{G} B^{sr}A^{rs}$.

In Eq. (13), the gross exports of the source country s are now decomposed into four elements: (i) value added exports, which are produced in country s and absorbed outside the source country $(= vt^{s*} = v^{s\prime} \sum_{g=1}^{G} B^{sg} (\sum_{r \neq s}^{G} f^{gr} + r^{g}))$, (ii) re-imports, which are initially exported (as intermediate inputs) but eventually returned and consumed in the source country (as intermediate inputs or as final products) $(= v^{s\prime} (\sum_{r \neq s}^{G} B^{sr} e^{rs}))$; (iii) Asian content[4], which is generated in endogenous countries and embodied (as imported inputs) in the source country's exports $(= v^{r\prime} \sum_{r \neq s}^{G} B^{rs} e^{s*})$; and (iv) imports from the ROW, which are induced by the source country's exports $(= m^{s\prime} \sum_{g=1}^{G} B^{sg} (\sum_{r \neq s}^{G} f^{gr} + r^{g}) + m^{s\prime} (\sum_{r \neq s}^{G} B^{sr} e^{rs}) + m^{r\prime} \sum_{r \neq s}^{G} B^{rs} e^{s*})$.

Eq. (13) corresponds to Eq. (34) of Koopman et al. (2012), but the former appears to be more complicated than the latter because it includes the terms relevant to (iv), imports from the ROW.[5]

3.2 Measures of the technological intensity of exports

As discussed in the previous section, the decomposition of gross exports demonstrates the following relation:

Gross exports= (i) value added exports + (ii) re-imports + (iii) Asian content + (iv) imports from the ROW. (14)

In Eq. (14), both components (iii) and (iv) represent value added that is generated

[4] Instead of "foreign content", the term "Asian content" will be used hereafter to clarify the difference between the ICIO and AIO tables.

[5] It is shown that gross exports are finally decomposed into nine elements in Koopman et al. (2012). In our method of decomposition, using the AIO tables, gross exports can be decomposed into a greater number of elements because of the terms relevant to the import from the ROW and exports to the ROW.

outside the exporting country. Thus, they should be separated from export values in examining the technology intensity of exports: note that only the value added that is generated by domestic factors of production should be included in such a measure.

In this regard, (i) should be included in the measure, because it represents the value added embodied in the exports and indirectly exported to the other countries. Re-imports, component (ii), are more nuanced. The re-imports contain the value added content that is initially exported but eventually returned and consumed in the exporting country. Therefore, its value added content is not actually exported (if we follow the definition of value added exports from Eq. (5)), although it is still a part of the domestic value added content that is induced by trade linkages. Thus, if we include the re-imports as a part of the domestic content (DC) of exports, DC contains both (i) the value added exports and (ii) the re-imports[6].

Originally, the technological intensity of exports was measured by the share of high-technology industry in exports (Lall, 2000). Now, there are two additional measures: one is the share of high-technology industry in value added exports, and the other is the share in domestic content (DC) of exports.[7] These measures will be

[6] The above treatment is in line with previous empirical studies on the Heckscher–Ohlin model. Since Leontief (1953) used a single country input–output table to measure the factor content of US trade, many studies have been conducted to test the Heckscher–Ohlin theorem with the use of input–output tables. In recent years, Trefler and Zhu (2010) used an international input–output table to estimate the Vanek-consistent factor content of trade. These studies focus on the factor content of trade, such as labor and capital inputs embodied in trade, because international trade is viewed as an indirect or disguised means of trading factor inputs embodied in trade. Meanwhile, the analysis of value added trade investigates the value added content (which is equivalent to factor inputs times factor prices) contained in trade.

[7] It is shown by Koopman et al. (2012) that a pure double-counted portion is included in the intermediate transactions of the re-imports. Thus, the domestic value added that is actually induced by exports (DV) is less than DC of exports. The author calculated the DVs for the countries covered in the AIO tables and found that the share of the pure double-counted portion is quite small (less than 0.5%), so that it does not significantly affect the export structure of the countries. Therefore, only the value added (VA) exports

employed to indicate the technological intensity of exports.

3.3 The indices of vertical specialization

The indices of vertical specialization are instrumental in demonstrating how a country is engaged in vertical production networks. There are two kinds of vertical specialization indices—VS and VS1— originally proposed by Hummels et al. (2001). The VS index indicates the foreign content of exports (equivalent to Asian content in the context of the AIO tables) and is given by

$$VS^s = \sum_{t\neq s}^{G} v^t B^{ts} e^{s*} = \sum_{t\neq s}^{G} \sum_{r\neq s}^{G} v^t B^{ts} \left[(A^{sr} x^r + f^{sr}) + r^s \right]. \qquad (15)$$

The VS1 index represents the domestic content of exports that are used as imported inputs by other countries to produce their exports; VS1 is given by

$$VS1^s = v^s \sum_{r\neq s}^{G} B^{sr} e^{r*} = v^s \sum_{r\neq s}^{G} \sum_{t\neq r}^{G} B^{sr} \left[(A^{rt} x^t + f^{rt}) + r^r \right]. \qquad (16)$$

Given the characteristics of these two indices, VS and VS1 are useful to obtain insights for a country's position in the vertical production networks. Because a country located in downstream depends heavily on imported inputs to be used for exports, it tends to have a high ratio of VS relative to gross exports (VS/EX). Upstream countries, in contrast, exports a large amount of intermediate inputs that are used by other countries to produce their exports, so they tend to have a high ratio of VS1 relative to gross exports

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and DC of exports are used as a measure of the technology intensity of exports. The other reason for using DC (rather than DV) is that DC is methodologically consistent with the VS and VS1 indices, which do not exclude a pure double-counted portion in their formulas.

(VS1/EX).

4 Results of empirical analysis

In this section, we first look at China's position in the regional production networks, with a particular focus on its linkages with Japan, South Korea, and Taiwan. After that, China's technology structure of exports is examined in greater detail.

4.1 China's position in the regional production networks

Table 1 shows the result of the decomposition of gross exports for China, Japan, South Korea, and Taiwan. As shown in Eqs. (13) and (14), gross exports are fully decomposed into four elements: value added exports (VA EX), re-imports (Re_IM), Asian content (AC), and imports from the ROW (IM_ROW). The table shows that China's gross exports continued to increase very rapidly, so that China's exports (885 billion USD) surpassed those of Japan (652 billion USD) in 2005. South Korea and Taiwan also increased their gross exports sharply, and their gross exports became close to half of Japan's in 2005. Figure 1 shows the decomposition of gross exports by percentage share. The shares of value added exports continued to fall in all four countries, while those of Asian content moved in the opposite direction. The increase in the share of Asian content obviously reflects deepening economic integration in East Asia, which has been accelerated by industry linkages spread across borders in the region. In particular, following Taiwan and South Korea, China sharply increased its Asian content and imports from the ROW in the subsequent periods. As a result, China's share of value added exports became significantly lower than that of Japan in 2005; this finding appears even more remarkable when taking into account the relative populations of China and Japan.

The other important finding is that the shares of re-imports were generally low, except in Japan. This is because Japanese firms actively invested in East Asian countries, particularly in China, and re-imported their intermediate and final products, while this type of linkage was relatively weak in other countries.

[Table 1]

[Figure 1]

Figure 2 shows the relative positions of the three countries in East Asian production networks. As discussed in the previous section, a country located downstream tends to have a high VS/EX ratio, while those located upstream have high VS1/EX ratios. In 1990, the Chinese economy was in its initial stage of regional integration, so it had a relatively low VS/EX ratio and VS1/EX ratio, but China has rapidly shifted downstream in the subsequent period, as reflected by a rising VS/EX ratio; this implies that China has increased dependency on intermediate inputs provided by neighboring East Asian economies. Japan, in contrast, was located upstream, and has been moving further upstream during the observed period. South Korea and Taiwan were initially located downstream, but they have rapidly moved upstream[8]. This parallels the shift in Japan and occurred due to a sharp increase in their intermediate exports to China.[9] In sum, specializations of East Asian economies have been changed in a systematic manner, as reflected in Figure 3.

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[8] Since South Korea and Taiwan have both a high VS1/EX ratio and a high VS/EX ratio, it can be said that they are located midstream in the regional production networks.

[9] The share of China's VS attributable to South Korea (which is calculated by Eq. (15)) increased sharply, from 4% to 19% during 1990–2005, while that attributable to Taiwan increased slightly, from 10% to 11%. The share attributable to Japan, in contrast, decreased, from 41% to 36%.

[Figure2]

[Figure 3]

4.2 Technology structure of China's exports

Table 2 shows the percentage shares of exports by technological level. The technological classification of exports is as given in Lall (2000), and all the original industry classifications in the AIO tables were converted into Lall's classification scheme.[10] As discussed in Section 2, the export structure of China continued to be upgraded, and the share of the high-technology manufactures in China's gross exports in 2005 (29.5%) finally exceeded that of Japan (19.5%). However, when measured by value added exports (respectively, DC of exports), the structure changes drastically: the share of the high-technology manufactures drops to 9.8% (resp., 9.9%) in 2005. Likewise, when measured by value added exports (resp., DC of exports), the share of high-technology manufactures declines substantially in Japan, South Korea, and Taiwan, but the decline in China is much sharper than in the others. Obviously, this reflects China's heavy dependence on imported inputs, particularly in high-technology manufactures.

These facts suggest the possibility of significant overestimation of China's technological intensity of exports. Furthermore, it is seen that 90% of China's

[10] Lall (2000) developed his original method of categorizing products by technology. The major categories of products are (i) high-technology manufactures (electronics and electrical products, and other high technology); (ii) medium-technology manufactures (automotive products, medium technology process industries, and medium technology engineering industries); (iii) low-technology manufactures (the textile/fashion cluster, and other low technology products); (iv) primary products; (v) resource-based manufactures (agriculture and forestry-based products, and other resource-based products).

high-technology exports in 2005 come from the electronics and electrical sector. This implies that the electronics and electrical sector is a major source of the overestimation.[11] It should, however, be noted that despite a serious concern over the overestimation, China's technological intensity of exports in terms of value added exports has increased considerably, from 4.9% to 9.8% during 1990–2005. This reflects the effects of China's substantial efforts at technological upgrading.

[Table 2]

Table 3 documents the decomposition of China's exports by technological level, where China's high-technology exports are decomposed into three elements: domestic content (DC), Asian content (AC), and imports from the ROW (IM_ROW). AC is further decomposed into elements either by country of origin (in the second section) or by sector of origin (in the third section). The fourth section gives the 10 highest country–industry combinations of value added content that are embodied in China's exports. Figure 4 shows the decomposition of China's exports by percentage share.

Table 3 indicates that China's high technology exports increased very sharply, from 7 billion USD to 261 billion USD, during 1990–2005. However, Figure 4 demonstrates that the share of the DC in all types of exports continued to decline over that period.

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[11] Note that the electronics and electrical sector has the most advanced and extensive production networks in East Asia. In particular, China plays a central role as an assembly base in the formation of a triangular trade structure (Haddad, 2007; Kuroiwa and Kuwamori, 2011). Thus, it is natural that the electric and electrical sector in China contains a large amount of import content (i.e., Asian content as well as imports from the ROW). See also the argument by Srholec (2007) in Section 2.3 of this paper: Srholec argues that high-technology exports, which comprise mostly electronics exports, can represent a mere reflection of high-technology component imports, particularly those of electronics components.

Also, it should be noted that high-technology exports contain less DC than medium- and low-technology exports do (here, 61%, 73%, and 76%, respectively, in 2005). In contrast, the dependency on import content (i.e., Asian content as well as imports from the ROW) continued to increase during 1990–2005; the Asian content of the high-technology exports, for example, increased from 7% to 16% in this period, during which Japan was the largest supplier of value added embodied in China's high-technology exports. Neighboring economies, and especially South Korea, have increased their shares rapidly.

[Table3]

[Figure 4]

The third section (of Table 3) demonstrates that services have been the largest supplier of value added content for China's high-technology exports, followed by high-technology manufactures. A similar structure can be observed for medium- and low-technology exports, although the next largest suppliers were, respectively, medium- and low-technology manufacturers.

The fourth section clearly indicates that Japanese manufacturers and services comprised important value added content of China's exports. In particular, China's high-technology exports require substantial amounts of Japanese services and high-technology manufactures (value added) content. It is important to note that in 1990, US industries were the second most important suppliers of value added content. In the subsequent period, however, South Korean and Taiwanese industries came to play a more significant role, so that their value added has been increasingly embodied in China’s exports.

5 Conclusion

This study focused on the technological intensity of China’s exports. It first introduced a method of decomposing gross exports by using the Asian international input–output tables. The empirical results indicated that the shares of value added exports in gross exports have continued to decline, while those of Asian value added content have risen in China and neighboring economies. As a result, the production networks involving China and its neighbors have been strengthened during the observed period.

Countries were placed in different positions in the regional production networks according to their stages of industrial development. In East Asia, China has rapidly moved downstream in the network. This implies that China has become increasingly dependent on its upstream economies, such as Japan, South Korea, and Taiwan for the procurement of the intermediate inputs used for high-technology exports.

The analysis of value added exports indicates that China’s technological intensity of exports has been significantly overestimated due to its high dependency on import content, especially in high-technology exports. Further, a large portion of value added embodied in China’s high-technology exports comes from relevant industries in neighboring economies. In particular, the Japanese services and high-technology manufactured good sectors are major suppliers of value added content. In a similar vein, South Korea and Taiwan have moved upward in the regional production networks and have overtaken the United States as a major supplier of value added contained in China’s high-technology exports.

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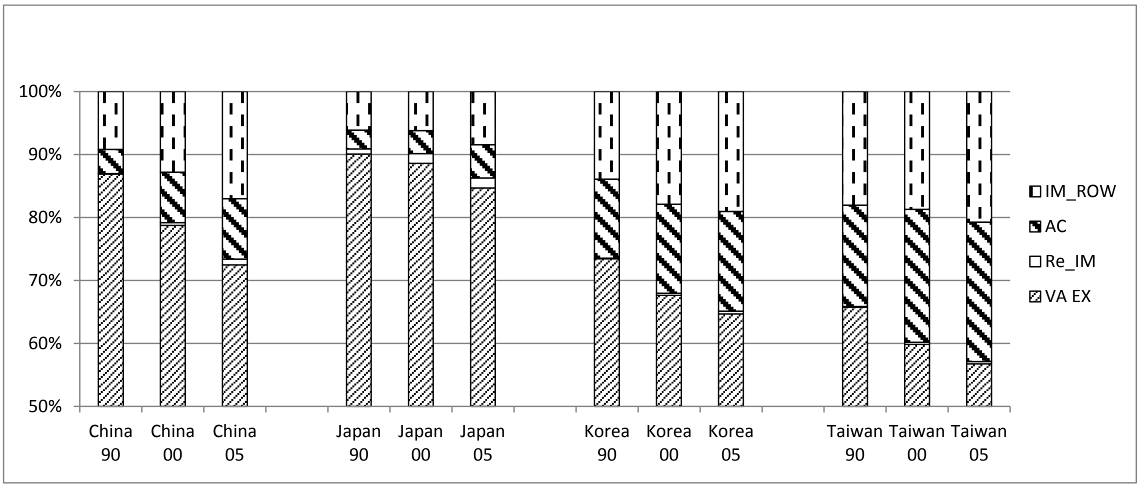
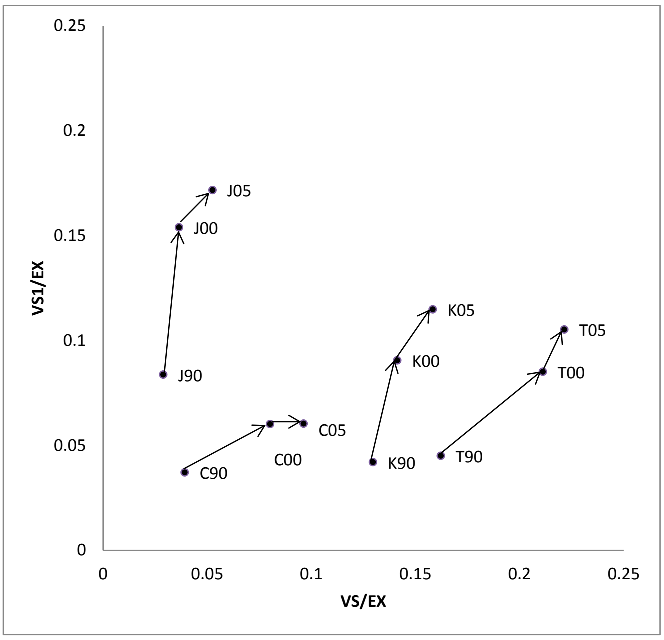
Figure 1 Decomposition of gross exports (percentage share)



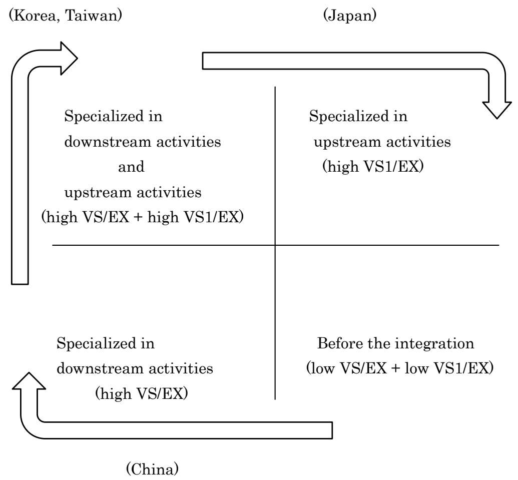
Source: Asian International Input–Output Tables, 1990, 2000, and 2005 (IDE-JETRO)

Figure 2 VS/EX and VS1/EX



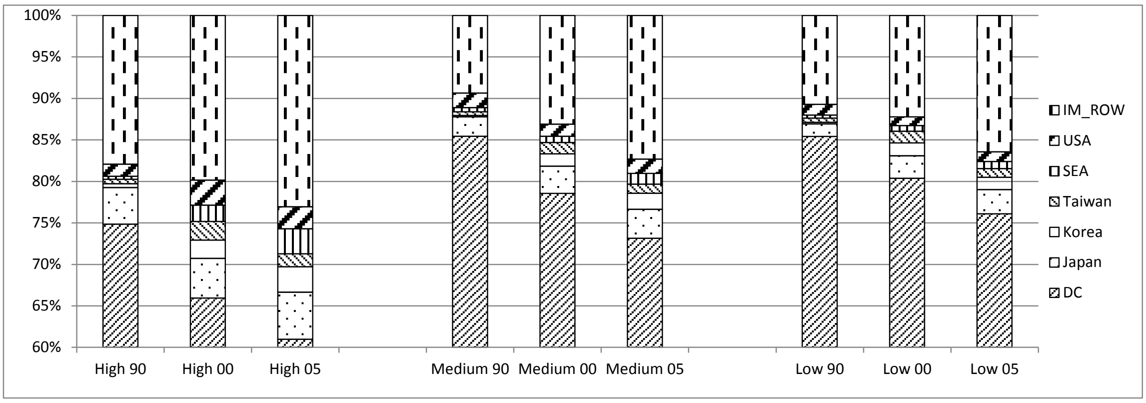
Source: Asian International Input–Output Tables, 1990, 2000, and 2005 (IDE-JETRO)

Figure 3 Changes in specializations of East Asian economies



Source: Asian International Input–Output Tables, 1990, 2000, and 2005 (IDE-JETRO)

Figure 4 Decomposition of China's exports by technological level (percentage share)



Source: Asian International Input-Output Tables, 1990, 2000, and 2005 (IDE-JETRO)

Table 1 Decomposition of gross exports (millions of USD)

1990	EX	VA EX	Re_IM	AC	IM_ROW
China	68,315	59,353	60	2,616	6,286
Japan	329,934	297,174	2,665	9,884	20,211
Korea	73,063	53,637	102	9,164	10,161
Taiwan	76,221	50,114	92	12,254	13,760

2000	EX	VA EX	Re_IM	AC	IM_ROW
China	300,525	236,655	1,260	24,107	38,503
Japan	530,626	470,150	8,228	19,394	32,855
Korea	205,027	138,688	652	28,972	36,716
Taiwan	176,161	105,404	601	37,207	32,949

2005	EX	VA EX	Re_IM	AC	IM_ROW
China	884,579	641,001	8,004	85,210	150,364
Japan	651,599	551,795	10,429	34,273	55,102
Korea	312,482	202,127	1,366	49,472	59,516
Taiwan	228,681	129,726	840	50,654	47,461

1) EX: exports; VA EX: value added exports; Re-IM: re-imports; AC: Asian content; IM_ROW: imports from the Rest of the World.

Source: Asian International Input–Output Tables, 1990, 2000, and 2005 (IDE-JETRO)

Table2 Distribution of exports by technological level (percentage share)

1990	China			Japan			Korea			Taiwan		
	EX	VA EX	DC	EX	VA EX	DC	EX	VA EX	DC	EX	VA EX	DC
High Tech*	11.9	4.9	4.9	25.1	14.5	14.5	19.6	10.2	10.2	22.2	9.3	9.3
Medium Tech	11.0	12.8	12.8	37.3	25.8	25.7	13.9	14.1	14.1	20.3	18.8	18.8
Low Tech	26.2	15.7	15.7	8.3	9.2	9.3	24.0	15.5	15.5	20.0	14.8	14.8
Primary products	11.6	29.0	29.0	0.2	1.6	1.6	1.5	6.8	6.8	1.2	4.2	4.2
Resource based	37.5	24.8	24.8	11.8	12.7	12.7	22.6	18.4	18.4	24.2	18.6	18.6
Service	1.8	12.7	12.7	17.4	36.3	36.2	18.4	35.0	35.0	12.1	34.2	34.2

2000	China			Japan			Korea			Taiwan		
	EX	VA EX	DC	EX	VA EX	DC	EX	VA EX	DC	EX	VA EX	DC
High Tech*	18.3	8.6	8.6	25.3	14.2	14.4	29.4	14.6	14.7	39.5	15.7	15.8
Medium Tech	20.1	15.7	15.7	44.3	26.8	26.7	26.4	18.4	18.4	21.1	14.6	14.6
Low Tech	34.4	21.6	21.6	7.7	9.5	9.6	16.9	14.3	14.3	19.0	13.6	13.6
Primary products	3.2	15.8	15.8	0.2	1.0	1.0	0.4	3.5	3.5	0.3	2.0	2.0
Resource based	9.9	10.8	10.8	3.2	5.0	5.0	8.4	8.9	8.9	4.6	5.3	5.3
Service	14	27.4	27.4	19.4	43.3	43.2	18.6	40.4	40.3	15.5	48.7	48.7

2005	China			Japan			Korea			Taiwan		
	EX	VA EX	DC	EX	VA EX	DC	EX	VA EX	DC	EX	VA EX	DC
High Tech*	29.5	9.8	9.9	19.5	10.5	10.6	31.0	15.3	15.3	42.5	21.8	21.9
Medium Tech	19.3	15.1	15.1	45.3	25.3	25.2	34.6	22.1	22.0	20.6	12.7	12.7
Low Tech	25.8	18.6	18.6	8.2	10.0	10.1	12.5	13.4	13.4	14.1	10.7	10.7
Primary products	2.0	14.3	14.3	0.1	0.9	0.9	0.2	2.6	2.6	0.8	2.0	2.0
Resource based	9.3	10.3	10.3	3.6	5.0	5.0	8.0	8.8	8.8	5.4	6.3	6.3
Service	14.1	31.8	31.8	23.2	48.3	48.2	13.7	37.9	37.9	16.7	46.5	46.5

1) Technological classification is based on Lall (2000).

Source: Asian International Input–Output Tables, 1990, 2000, and 2005 (IDE-JETRO)

Table 3 Decomposition of China's exports by technological level (millions of USD)

1990	High		Medium		Low
Exports	7,289		8,434		22,343
DC	5,456		7,206		19,085
AC	527		440		866
Japan	321		197		337
Korea	34		15		47
Taiwan	39		38		112
SEA	26		43		85
USA	106		147		286
High (H)	137		12		13
Medium (M)	99		167		200
Low (L)	62		67		201
Primary (P)	21		27		100
Resource (R)	54		43		103
Service (S)	154		123		250
J-S	97	J-M	70	J-L	124
J-H	88	U-M	61	U-S	99
J-M	56	J-S	55	J-S	97
J-L	44	U-S	48	J-M	69
U-S	34	J-L	45	U-M	63
J-R	32	T-M	18	U-P	62
U-H	25	J-R	17	T-M	39
U-M	24	U-R	13	J-R	35
K-H	12	U-P	12	U-L	30
T-M	11	U-L	11	U-R	29
IM_ROW	1,306		788		2,392

2000	High		Medium		Low
Exports	54,951		60,325		103,486
DC	36,237		47,389		83,180
AC	7,814		5,040		7,666
Japan	2620		1985		2796
Korea	1217		892		1615
Taiwan	1237		818		1462
SEA	1090		468		701
USA	1650		878		1093
High (H)	2,780		330		365
Medium (M)	1,009		1,443		1,336
Low (L)	579		829		2,129
Primary (P)	188		203		381
Resource (R)	385		359		612
Service (S)	2,873		1,877		2,843
J-S	986	J-S	755	J-S	1,095
J-H	767	J-M	628	J-L	833
U-S	650	T-S	367	T-S	651
U-H	641	U-S	355	K-L	591
T-S	525	J-L	354	J-M	535
K-H	480	K-M	262	K-S	461
J-M	451	K-S	257	U-S	442
T-H	413	U-M	255	T-L	439
K-S	351	T-M	210	K-M	277
J-L	247	K-L	190	T-M	226
IM_ROW	10,901		7,896		12,640

2005	High		Medium		Low
Exports	261,327		171,059		227,958
DC	159,404		125,126		173,471
AC	41,667		16,338		17,015
Japan	14,762		5,986		6,651
Korea	8,060		3,303		3,381
Taiwan	4,042		1,871		2,417
SEA	7,927		2,211		1,910
USA	6,877		2,967		2,657
High (H)	14,787		1,241		948
Medium (M)	4,254		4,538		2,344
Low (L)	2,824		2,053		4,622
Primary (P)	1,078		786		846
Resource (R)	1,688		929		1,053
Service (S)	17,035		6,791		7,203
J–S	6,637	J–S	2,749	J–S	3,002
J–H	4,130	J–M	1,679	J–L	1,923
K–H	3,444	U–S	1,339	K–L	1,268
U–S	3,208	K–S	1,177	U–S	1,252
K–S	2,648	K–M	953	T–S	1,232
U–H	2,307	U–M	933	K–S	1,137
J–M	1,966	J–L	866	J–M	1,007
T–H	1,640	T–S	848	T–L	642
T–S	1,608	K–L	553	U–L	523
M–S	1,406	T–M	489	K–M	446
IM_ROW	60,256		29,595		37,472

1) Technological classification is based on Lall (2000).

2) It holds that Exports=DC+AC+IM_ROW for all the columns in the first and fifth sections of the Table. In the second section, AC is decomposed into five countries or regions (where SEA represents the five Southeast Asian countries that are covered in the AIO tables). In the third section, AC is decomposed into six sectors: high-technology manufactures (H); medium-technology manufactures (M); low-technology manufactures (L); primary products (P); resource-based industry (R); and services industry (S). The fourth section lists the top 10 combinations of country and industry, in terms of value-added content: J–S, for example, represents the services industry (S) of Japan (J), which provided the largest value added embodied in China's high-technology exports for 1990, 2000, and 2005. Regarding the country codes, J, K, T, U, and M respectively stand for Japan, South Korea, Taiwan, the United States, and Malaysia.

Source: Asian International Input–Output Tables, 1990, 2000, and 2005 (IDE-JETRO)