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Abstract

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Keywords: Industrial deepening, production networks, input-output analysis
JEL classification: C67, O14

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Structural transformations are an indispensable element of sustained economic growth. Within the context of East Asia, this study focuses on industrial deepening, which refers to the formation of local linkages and the creation of a robust local supplier base. To investigate the progress of industrial deepening, this study introduces two kinds of domestic procurement measures in addition to the previously developed local content measures. Specifically, two kinds of vertical specialization measures are used to demonstrate the degree to which respective East Asian economies are specialized within their vertical production networks. The results clearly show that the advancement of production networks is likely to reduce domestic procurement ratios, even if local supplier bases are strengthened in the respective countries. Moreover, the trend of domestic procurement ratios differs depending on the characteristics of particular industries and the industrial policies adopted by individual countries.

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1. Introduction

It is often pointed out that local supplier bases in Southeast Asia are relatively weak in comparison with those in Northeast Asian countries, such as China, Korea, and Taiwan. As discussed below, the formation of industrial linkages and the development of local supplier bases are crucially important in terms of strengthening the competitiveness of industries and sustaining economic growth. However, the empirical evidence is still lacking due to a paucity of appropriate data.

This study focuses on industrial deepening and local supplier development in East Asia. Here, industrial deepening implies the formation of local linkages and complementarities through the creation of a robust local supplier base and the expansion of ancillary services (Asian Development Bank 2013). More specifically, the study focuses on the formation of industrial linkages within a country and in doing so attempts to measure the strength of linkages using the international input-output approach.

The formation of domestic linkages affects the economy of a country in several ways. Firstly, the linkages tend to promote structural transformations such as industrial structures being diversified or upgraded. Industrialization often starts with low-skill, low-value-added downstream activities, such as final assembly. It then gradually shifts toward high-skill, high–value-added upstream activities, which require more sophisticated technology and greater economies of scale in production. Since A. O. Hirschman published a seminal book on economic development strategy (Hirschman 1958), such industrial linkages have become a focal point in industrial development. In particular, so-called backward linkages play a critical role by inducing demand for upstream activities and thus stimulate industrial development in sequence—from

downstream final assemblers, to first-tier parts and components suppliers, and then to second and lower-tier suppliers. The production of basic materials and machinery is therefore stimulated by the advancement of downstream activities.

Secondly, the development of upstream industries and the formation of domestic linkages decrease dependency on imported inputs. This process contributes to lowering trade deficits, which are faced by many developing countries due to the lack of a robust local supplier base.

Thirdly, the development of upstream industries increases the competitiveness of downstream industries by delivering parts and components at lower costs, in a shorter time, and with more flexibility.[1] Moreover, if both upstream and downstream industries are co-located within industrial clusters, frequent communication and information exchange between assemblers and parts suppliers stimulate innovation (Porter 1990).

Fourthly, industrial linkages create an important channel for technology transfer. In particular, the formation of backward linkages promotes knowledge and technology spillover from foreign-affiliated firms to local supplier firms (Javorcik 2004, Blalock and Gertler 2008).

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[1] Due to these effects, the downstream (assembling) industries are attracted to a country or region where the upstream industries (parts, components, and materials) are located. Such agglomeration effects are called “forward linkage effects”. On the other hand, upstream industries are attracted to countries or regions in which downstream industries are located because the latter provide intermediate demand for the former (i.e., “backward linkage effects”). Both the forward and backward linkage effects cumulatively promote the formation of industrial clusters (Krugman and Venables 1995, Puga 1999).

Finally, it is often pointed out that the expansion of production networks has increased the vulnerabilities of the networks with regard to external shocks such as economic crises and natural disasters (Fujita and Hamaguchi 2014).[2] The deepening of domestic linkages could therefore reduce such vulnerabilities.

To investigate the process of industrial deepening in East Asia, this study uses the Asian International Input-Output Tables (hereinafter, AIO tables) for 1975, 1990, and 2005, which were compiled by the Institute of Developing Economies (IDE-JETRO). The AIO tables cover nine East Asian economies—China, Japan, Korea, Taiwan, Indonesia, the Philippines, Thailand, Malaysia, and Singapore—plus the United States. In this study, however, the four middle-income Southeast Asian countries of Malaysia, Thailand, Indonesia, and the Philippines are treated separately as a single group (hereinafter, the SE4) and will be compared with China, Japan, and Korea. The AIO tables indicate the transaction matrices of imported inputs as well as domestic inputs. These tables are therefore instrumental in showing how imported inputs have been substituted by domestic inputs as a result of the development of domestic linkages.

Regarding our chosen methodology, this study introduces two kinds of domestic procurement measures (domestic procurement ratios), which are used in addition to the previously developed local content measures (Kuroiwa 2009). These measures indicate the strength of domestic linkages in comparison with international linkages. Finally, two kinds of vertical specialization measures (VS and VS1) are introduced to show how

[2] Kuroiwa and Kuwamori (2011) demonstrated that the global financial crisis (2007-2009) seriously affected East Asian economies through the production network centered on China. For instance, 33.7 percent of the production shock that Korea's computer and electronic equipment sector received due to the decline in US import demand during 2008Q3 – 2009Q1 originated in the inter-country spillover effects through China.

respective East Asian economies are specialized in relation to vertical production networks in the region. Note that to fully utilize the advantages of international input-output data, the main focus will be placed on both domestic and international procurement. It will be shown that the specialization of each economy, whether specialized in upstream or downstream manufacturing activities, closely reflects the development of domestic linkages as well as international linkages.

The paper first describes the factors that affect the formation of domestic linkages. After that, the method of analysis is presented, with a focus on the newly introduced domestic procurement measures. The paper then goes on to examine the results of the empirical analyses before concluding with a summary and discussion of important findings.

2. Formation of domestic linkages

The factors that affect the formation of domestic linkages are multifaceted. Some are driven by market forces, while others are induced by policy measures. For example, the spatial economics literature demonstrates how backward linkage effects induce the growth of upstream industries, while forward linkage effects encourage the expansion of downstream industries (see Krugman and Venables (1995) and Puga (1999) for general equilibrium models with industrial agglomeration caused by industrial linkages). In particular, when the trade costs of imported inputs are sufficiently high, the procurement of intermediate inputs from domestic sources increases.

On the other hand, the expansion of vertical production networks negatively affects domestic linkages. For example, when production fragmentation occurs, large volumes of inputs are imported to facilitate processing, but the resulting products are exported

back into the international market. Consequently, growing production fragmentation, coupled with a rapid increase in intermediate trade, is likely to strengthen external linkages at the expense of the domestic linkages. However, an increase in the international division of labor may well enhance the efficiency and competitiveness of the affected domestic industries.

It should also be noted that certain types of industrial policy affect the formation of domestic linkages. For instance, local content requirements, which had been adopted by developing countries until the Agreement on the Trade-Related Investment Measures (TRIMs) was implemented after the Uruguay Round, strictly regulated the share of domestic inputs. From the viewpoint of firms, imported parts and components can be substituted by domestic production as long as the increased costs associated with import substitution are compensated for by the higher tariff protection for final products.[3] Moreover, the governments of some developing countries have actively intervened to establish linkages between foreign assemblers and local suppliers by providing relevant information, financial assistance, and fiscal incentives, as in the Vendor Development Program and the Industrial Linkage Program in Malaysia. Such policy interventions can be instrumental in deepening a country's domestic linkages.

In contrast, trade liberalization and other export-promotion measures, such as import duty exemptions and duty drawbacks, lower the trade costs of imported inputs.

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[3] For example, the Ministry of Industry of Thailand imposed a minimum local content requirement of 25 percent on the automotive assemblers in 1975. Then the Ministry of Commerce prohibited imports of passenger cars in 1978, while the Ministry of Industry raised the minimum local content requirement up to 50 percent; in the late 1980s, the Thai government mandated the local production of diesel engines (a key component of pickup truck manufacturing). As a result of such policy interventions, the local content of the Thai automotive industry has increased remarkably.

Likewise, investment in transport infrastructure and trade facilitation lowers trade costs. These policy measures are likely to encourage production fragmentation and strengthen external linkages at the expense of domestic linkage development (Tham and Loke 2011).

3. Methodology

To analyze the formation of domestic linkages, this study first investigates the local content of East Asian industries. Local content indicates the share of value added that is generated domestically. There are two types of local content measures, depending on how intermediate transactions are treated.

3.1 Local content: direct measure

Local content is the most commonly used indicator showing the share of domestic resources used in production and can be calculated using the following formula:

$$lc_j^S = (\sum_{i=1}^{n} X_{ij}^{SS} + V_j^S) / X_j^S = \sum_{i=1}^{n} a_{ij}^{SS} + v_j^S . \quad (1)$$

Here, lc_j^S denotes local content of sector j in country S; X_{ij}^{SS} is the amount of an intermediate input, that is, commodity i, in country S needed by sector j in country S; V_j^S and X_j^S respectively represent the value added and output of sector j in country S; n is the number of sectors in each country; $\sum_{i=1}^{n} a_{ij}^{SS}$ and v_j^S respectively represent the

sum of domestic intermediate input coefficients and the value added coefficient of sector j in country S.[4]

As shown in Equation (1), local content is the sum of intermediate input coefficients and value added coefficients. Thus, only the direct input structure is taken into account and no roundabout processes of production are involved, making this the "direct measure" of local content. Simultaneously, it holds that $mc_j^S = (1 - lc_j^S)$, where mc_j^S represents import content of sector j in country S.

3.2 Local content: total measure

It is obvious that the direct measure does not represent true local content. This is because even if intermediate inputs are provided by domestic suppliers, they may require additional imported materials in their upstream production processes. If so, value added will not accrue entirely within domestic industries and there will be leakage of value added to foreign suppliers. To illustrate, if an engine is supplied directly by a first-tier domestic supplier, this portion will be given 100 percent originating status in the direct measure. However, to produce an engine, the first-tier supplier may need to import a substantial amount of intermediate inputs such as engine parts and metallic materials due to a lack of second-tier suppliers and lower in the domestic market. As a consequence, the true local content may be significantly lower than the direct measure indicates. In particular, such a disparity regarding local

[4] Note that lc_j^S in Equation (1) is consistent with the formula as stipulated by the value added criterion, which is one of the most frequently used rules of origin in trade agreements (Matsumura and Fujikawa 1998, Kuroiwa 2009).

content will be large if the economy lacks well-established upstream industries. True local content is calculated by computing the proportion of valued added accruing to domestic industries from the entire (i.e., direct as well as indirect) production processes. Consistent with the notation described above, the matrix indicating value added induced by one unit of demand for each sector is given by

$$[\gamma_{ij}^{RS}] = \mathbf{\Gamma} = \hat{\mathbf{V}}(\mathbf{I} - \mathbf{A})^{-1}, \qquad (2)$$

where $\hat{\mathbf{V}}$ and $\mathbf{A}$ respectively represent a diagonal matrix of value added coefficients and an input coefficient matrix of the AIO tables. γ_{ij}^{RS} (an element in matrix $\mathbf{\Gamma}$) indicates the value added that is induced by one unit of demand for sector *j* in country *S* and that accrues to sector *i* in country *R*. Then, true local content can be calculated as follows:

$$lc*_j^S = \sum_{i=1}^{n} \gamma_{ij}^{SS}. \qquad (3)$$

Here, $lc*_j^S$ represents the share of value added accruing to all domestic industries in country *S* and $1 - lc*_j^S$ represents the share of value added leaked to other countries. Local content given by Equation (3) may be termed the "total measure" of local content, since the measure takes into account both direct and indirect inputs[5].

[5] In this context, it should be noted that Equation (3) is methodologically consistent with the analysis of trade in value added. Trade in value added indicates the flow of value added that is produced in a source country but consumed (as final demand) in a destination country (Johnson and Noguera 2012, Koopmans et al. 2012). Equation (3) gives the share of value added that is generated within a country when one unit of demand is given in sector *j* in country *S*. Trade in value added can be calculated by post-multiplying Equation (2) by final demand vector (see Kuroiwa 2014).

3.3 Domestic procurement ratio

Although local content indicates the share of domestic resources employed by each sector (domestic intermediate inputs plus value added), it overestimates dependency on domestic suppliers because each sector's own value added (V_j^S) is always included in the local content of that sector. It would therefore be more appropriate to exclude value added from the equation and calculate the ratio of domestic intermediate inputs to total (domestic plus imported) intermediate inputs used by each sector. Note that such a ratio can be obtained by deducting a sector's own value added (V_j^S) from both the numerator and denominator in Equation (1). Then, the domestic procurement ratio in direct measure is given by

$$dp_j^S = \sum_{i=1}^{n} X_{ij}^{SS} / (X_j^S - V_j^S) = \sum_{i=1}^{n} a_{ij}^{SS} / (1 - v_j^S), \qquad (4)$$

where $\sum_{i=1}^{n} X_{ij}^{SS}$ and $(X_j^S - V_j^S)$ respectively represent domestic and total intermediate inputs used by sector *j* in country *S*. Analogously, the domestic procurement ratio in total measure is calculated as follows:

$$dp^*_j{}^S = (\sum_{i=1}^{n} \gamma_{ij}^{SS} - v_j^S) / (1 - v_j^S) = \sum_{i=1}^{n} \phi_{ij}^{SS} / (1 - v_j^S), \qquad (5)$$

where $[\phi_{ij}^{RS}] = \Phi = \hat{\mathbf{V}}[(\mathbf{I} - \mathbf{A})^{-1} - \mathrm{I}] = \hat{\mathbf{V}}[\mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 ...]. \qquad (6)$

Note that in Equation (5), a sector's own value added (v_j^S) is deducted from both the numerator and the denominator in Equation (3). This implies that Equation (5) represents the share of domestic value added that is generated after the first round repercussion effects (i.e., in the second, third, fourth, … round repercussion effects), where the repercussion effects of these rounds are respectively captured by $\hat{\mathbf{V}}\mathrm{I}$, $\hat{\mathbf{V}}\mathbf{A}$, $\hat{\mathbf{V}}\mathbf{A}^2$, $\hat{\mathbf{V}}\mathbf{A}^3$, … (see Equation (6)). Note that the first round repercussion effects always

accrue in the sector itself. Therefore, such repercussion effects should be excluded to avoid the overestimation of the dependency on domestic procurement.

As an extension of Equations (4) and (5), the following equations show the shares of domestic procurement in sector i used by sector j in country S.

$$dpm_{ij}^{S} = X_{ij}^{SS} / \sum_{R=1}^{G+1} X_{ij}^{RS} = a_{ij}^{SS} / \sum_{R=1}^{G+1} a_{ij}^{RS}, \quad (7)$$

$$dpm*_{ij}^{S} = \gamma_{ij}^{SS} / \sum_{R=1}^{G+1} \gamma_{ij}^{RS}, \quad (8)$$

where G is a number of endogenous countries in the AIO tables.[6] Note that these measures indicate the shares of domestic procurement in the direct and total measures, respectively.

3.4 Vertical specialization measure

The indices of vertical specialization are instrumental in demonstrating how a country is specialized in vertical production networks. The two vertical specialization measures ("VS" and "VS1") were originally proposed by Hummels et al. (2001) and then extended to international input-output analysis by Koopmans et al. (2012). The VS index indicates the foreign content of exports, which is leaked to other countries when a country imports inputs to produce its exports. VS for country S is given by

$$VS^{S} = \sum_{R \neq S}^{G} \mathbf{\Gamma}^{RS} e^{S}, \quad (9)$$

where $\mathbf{\Gamma}^{RS}$ and e^{S} are respectively a sub-matrix of $\mathbf{\Gamma}$ in Equation (2) and an export vector of country S. Since $\mathbf{\Gamma}^{RS} e^{S}$ represents the value added that is generated in

[6] The Rest of the World is treated exogenously in the AIO tables, but inputs from the Rest of the World are included in the denominators of both Equations (7) and (8). Note that such treatment gives them consistency with Equations (1) to (6).

country R by country S' exports, VS^S indicates the total value added that is generated in all the endogenous countries excluding country S, by country S'exports.

The VS1 index, on the other hand, represents the domestic content of exports used as intermediate inputs by other endogenous countries to produce its exports. VS1 for country S is given by

$$VS1^S = \sum_{R \neq S}^{G} \mathbf{\Gamma}^{SR} e^R. \quad (10)$$

Given the characteristics of these two indices, VS and VS1 are instrumental in obtaining insights into a country's position regarding its vertical production networks. That is to say, a country specialized in downstream manufacturing operations needs to import a large amount of inputs (for its own exports) and thus has strong (cross-country) backward linkage effects. Such a country tends to have a high ratio of VS relative to gross exports (EX). On the other hand, a country specialized in upstream operations exports a large amount of inputs (for other countries' exports) and thus has strong forward linkage effects. Such a country tends to have a high VS1/EX ratio.[7]

As will be discussed below, it is, however, possible that both VS/EX and VS1/EX ratios increase simultaneously if a country is deeply involved in vertical regional production networks and increases the intra-industry trade of inputs significantly.

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[7] Note that in standard input-output analysis, the hierarchical relationships between industries are detected by the triangularization of input-output tables (Chenery and Watanabe 1958; Simpson and Tsukui 1965). On the other hand, the VS/EX and VS1/EX ratios are instrumental in revealing the hierarchical relationships between countries in the context of vertical production networks. It should be noted, however, that unlike the triangularization method, the VS/EX and VS1/EX ratios capture only the bilateral relationship between the supplier country and the demander country, as shown in countries r and s in Equations (9) and (10).

4. Empirical results

In this study, East Asian countries are divided into four groups, namely, the SE4, China, Japan, and Korea. As indicated previously, the SE4 group comprises four middle-income Southeast Asian countries, namely, Malaysia, Thailand, Indonesia, and the Philippines.

4.1 Local content

Figures 1-1 to 1-4 show the local content of industries in the SE4, China, Japan, and Korea in 2005.[8] It can be observed that the SE4 had a relatively low local content. This was particularly notable in the machinery sectors, where electrical machinery had the lowest local content (60 percent in the direct measure).

[Figures 1-1, 1-2, 1-3, 1-4 around here]

In contrast, China and Japan had relatively high local content, but China had a lower local content than Japan in several manufacturing sectors, particularly in electrical machinery (78 percent). Japan, on the other hand, had an extremely high local content that exceeded 80 percent (in the direct measure), except for chemical products (70 percent). Likewise, Japan had a relatively low local content in electricity, gas, and water supply (85 percent). Note that the local content of these two sectors was also low in Korea (61 percent and 70 percent, respectively), reflecting their high dependency on imported raw materials, particularly crude petroleum.

[8] Local contents in 1975 and 1990 are not shown here due to the limitation of space. For structural changes over the period 1975-2005, the domestic procurement ratios are demonstrated in the following section.

Korea had a lower local content than Japan, and this was significantly lower in electrical machinery (68 percent).

The above tendency is more clearly demonstrated when the total measure is used to indicate the true local content of industries. Total measures are significantly lower than direct measures, and this implies significant leakages of value added in roundabout production processes.[9] In particular, those industries that are heavily dependent on imported inputs in their upstream operations tend to have high leakages of value added. In the SE4, China, and Korea, the manufacturing sectors had relatively high leakages in excess of 10 percent (see the curves labeled "DM − TM" in Figures 1-1 to 1-4). Among these, manufacturing sectors in Korea had very high leakages—exceeding 20 percent in metal products, transport machinery, and other manufacturing—while those in Japan were significantly lower.

4.2 Domestic procurement ratio

Machinery sectors constitute the core elements of manufacturing industrial development. Moreover, machinery sectors use a large amount of intermediate inputs due to the complex and lengthy roundabout processes of production. They also have a relatively high dependency on imported inputs due to technological difficulties and scale economies in production, particularly in developing countries. It is therefore highly relevant to focus on the machinery sectors and examine trends in their domestic procurement ratios over the period 1975-2005.

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[9] Note that the disparities between direct measures and total measures also indicate error margins (specifically, overestimates) that occur when calculating local content using the formula as stipulated by the value added criterion in the rules of origin for trade agreements (Kuroiwa 2009).

Table 1 shows that among the four economies considered here, the SE4 had on average the lowest domestic procurement ratios in the machinery sectors. In particular, general machinery, electrical machinery and transport machinery had total domestic procurement ratios of less than 40 percent in both 1990 and 2005. In China, all the machinery sectors, except for transport machinery, experienced decreased domestic procurement ratios in the same period; this clearly reflects China's growing participation within East Asian production networks.[10] A similar phenomenon can be observed in Japan, where its machinery sectors were previously highly self-sufficient with extremely high direct domestic procurement ratios (95 percent or more in 1975), but these have gradually declined over time.

[Table 1 around here]

In contrast, Korea's machinery sectors, excluding electrical machinery, exhibited significant increases in domestic procurement ratios during the period 1975-2005. As a result, in 2005 the domestic procurement ratios of general machinery and transport machinery respectively reached 87 percent and 85 percent (direct measures). It should be noted, however, that Korea's domestic procurement ratios drop sharply (by more than 20 percent in some sectors) when determined as the total measure.

Tables 2-1 to 2-4 indicate domestic procurement ratios for materials, parts, and components used by the machinery sectors (Equations (7) and (8)). Among the material

[10] China is not covered in the 1975 ASEAN table. As such data on China are available for only 1990 and 2005.

inputs, only chemical products, metal products, and non-metallic mineral products are reported in the tables, while parts represent intermediate inputs provided and used by respective sectors (e.g., electrical machinery parts used by the electrical machinery industries).

[Table 2-1, 2-2, 2-3 2.4 around here]

It is notable that the SE4's general machinery and transport machinery exhibit relatively low domestic procurement ratios for metal products. This reflects the fact that the SE4 still lacked a robust local supplier base for the metal industry, including iron and steel. In contrast, China and Japan had extremely high domestic procurement ratios, except for parts and components for electrical machinery and precision machinery in China. However, a great number of domestic procurement ratios continued to decline, particularly in the case of Japan. For instance, Japan's transport machinery sector experienced decreased domestic procurement ratios for chemical products, metal products, non-metallic minerals, and parts during the period 1975-2005. Korea's machinery sectors, on the other hand, demonstrated an upward trend except for electrical machinery, where domestic procurement ratios for chemical products and metal products were on downward trends.

Chemical products and metal products had greater differences between the direct and total measures than did non-metallic mineral products. This reflects the fact that these two industries are highly dependent on imported raw materials such as crude petroleum and iron ore.

With regard to parts and components provided and used within a sector itself, the SE4's transport machinery sharply increased domestic procurement ratios from 25 percent to 63 percent (direct measures) during the period 1975-2005. Likewise, Korea's transport machinery increased domestic procurement ratios from 64 percent to 92 percent. Japan and China also had very high domestic procurement ratios at 97 percent and 88 percent, respectively, in 2005. Moreover, domestic procurement ratios for transport machinery, which cover all intermediate inputs (i.e., materials, parts and components) used by respective sectors, continued to increase except for Japan (Table 1). It is worth noting that this upward trend in domestic procurement ratios was considered to be associated with significant economies of agglomeration, which are generated by industrial linkages in transport machinery.[11] It is also highly likely that local content requirements imposed on the sector affected domestic procurement ratios (see footnote 3).

On the other hand, electrical machinery had relatively low domestic procurement ratios for parts and components, and these ratios were following downward trends over the period 1975-2005, with the exception of Korea. Japan's electrical machinery, for instance, decreased them from 96 percent to 73 percent (direct measures) over this period. Furthermore, electrical machinery had relatively low domestic procurement ratios and these showed a declining trend in all countries (Table

[11] For instance, parts and components for automobiles are heavy and bulky. Thus their transport costs are significantly higher than many other industries. Geographical proximity not only lowers transport and invent costs—or facilitate the "just-in-time delivery" as in case of Toyota—but also facilitates product development coordination between parts suppliers and assemblers (Baba 2005; Dyer 1994, 1996). Significant economies of agglomeration are also observed in other transport machinery industries that have high transport costs of parts and components.

1). Note that such a downward trend in domestic procurement ratios reflects the fact that electrical machinery is highly export-oriented and has established extensive production networks in East Asia (Baba 2005).

4.3 Vertical specialization measures

The intra-industry trade of intermediate inputs has increased sharply in East Asia.[12]. Simultaneously, due to differences in their stages of industrial development, some countries are more specialized in upstream manufacturing activities, while others are more specialized in downstream activities. This section considers how respective countries were specialized within East Asian production networks and how they have changed their roles and positions within them. Note that the specialization of respective countries reflects advancements in international linkages, but this is actually a reflection of domestic linkages as well.

As illustrated above, a country that is specialized in downstream activities tends to have a high VS/EX ratio, while a country specialized in its upstream activities tends to have a high VS1/EX ratio. Figure 2 shows VS/EX and VS1/EX ratios for all manufacturing sectors (Sectors 3 to 15) combined,[13] while Tables 4-1 and 4-2 respectively demonstrate percentage shares of VS and VS1 by trade partner, that is, the percentage shares of country R in Equations (9) and (10).

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[12] For the advancement of intra-industry trade of intermediate inputs in East Asia, see Appendix 1.

[13] This is equivalent to average VS/EX and VS1/EX ratios for all manufacturing sectors combined, weighted by the share of exports of each manufacturing sector. For VS/EX and VS1/EX ratios of each manufacturing sector in 2005, see the Appendix 2.

[Figure 2 around here]

It is notable that the SE4 sharply increased its VS/EX ratios during the period 1975-1990, and became deeply involved in East Asian production networks as final assemblers of imported inputs [14] Similarly, China participated in the regional production networks, and this is reflected in significant increases in its VS/EX ratios during the period 1990-2005. It should be observed, however, that the SE4's VS1/EX ratios also increased substantially during the period 1990-2005, which implies that they started to be specialized in exports of intermediate inputs as well.

Japan used to have very low VS/EX ratios, which is a reflection of the extremely high self-sufficiency levels of Japanese manufacturing industries, but gradually increased its VS/EX ratios during the period 1975-2005. During this time, Japan became increasingly specialized in its upstream activities, as reflected by rapid increases in its VS1/EX ratios. Note that both the rising VS/EX ratio and the rising VS1/EX ratio are in line with the increasing intra-industry trade of intermediate inputs. In this regard, Korea is quite different from other countries. Korea's VS/EX ratio used to be very high, but has gradually declined. At the same time, Korea increased its VS1/EX ratios sharply.

Regarding the percentage shares of VS and VS1 by trade partners, Table 3-1 shows that Japan previously had very high shares of VS in all the included countries. This implies that a large amount of Japan's value added content was contained in their exports due to a high dependency on intermediate inputs from Japan. However, the

[14] Note that foreign direct investment in the SE4 increased rapidly after the mid-1980s. These economies then joined East Asian production networks as final assemblers of manufactured products.

other countries substantially decreased their dependency on Japan (for instance, from 69 percent to 35 percent in the SE4; from 61 percent to 41 percent in Korea) during the period 1975-2005, although Japan still provided the highest share of value added content in 2005. China, Korea, and the SE4, on the other hand, increased their shares of VS, gradually eroding Japan's position as a dominant supplier of inputs. At the same time, Japan increased its value added content from other countries, particularly China and Korea.

[Table 3-1, 3-2 around here]

Table 3-2 shows that, in 2005, China increased its shares of VS1 and came to have the highest shares in all the countries. In particular, Korea's dependency on China's exports increased very rapidly (from 4 percent to 46 percent during the period 1990-2005). In a similar vein, Japan increased its dependency on China's exports, while other countries decreased their dependency on Japan's exports over the period 1975-2005.

In summary, it has been clearly shown that after less developed countries, such as the SE4 and China, joined East Asian production networks they initially increased their dependency on imported inputs. Over time they also gradually increased exports of intermediate inputs. On the other hand, more developed countries such as Japan and Korea were becoming increasingly specialized in their upstream activities. Moreover, while a highly self-sufficient economy like Japan increased its dependency on imported inputs, Korea demonstrated an opposite trend. It is therefore noteworthy that such a downward trend in Korea's VS/EX ratio is a reflection of the deepening of domestic

linkages; in particular, the trend in a VS/EX ratio is closely associated with those in domestic procurement ratios of each country. ,.

5. Conclusion

This study has demonstrated that the industrial deepening is crucially important for a country to achieve sustainable economic growth. First, industrial deepening will promote structural transformations. Second, it will contribute to a reduction in trade deficits. Third, it will increase the competitiveness of relevant industries. Fourth, it constitutes an important channel for technology transfer. Finally, it will reduce a country's vulnerabilities with regard to external shocks.

To investigate the progress of industrial deepening, this study introduced two kinds of domestic procurement measures, in addition to the previously developed local content measures. Moreover, two kinds of vertical specialization measures were used to demonstrate how respective East Asian economies were specialized in terms of their vertical production networks.

The findings reveal that the SE4, comprising Malaysia, Thailand, Indonesia, and the Philippines, had relatively low domestic procurement ratios, particularly in the machinery sectors. Moreover, their participation in East Asian production networks has led to an increased dependency on imported inputs. A similar phenomenon has also occurred in China as its manufacturing industries used to be highly self-sufficient, but participation in associated production networks has increased China's dependency on imported inputs.

The Japanese manufacturing sectors were shown to be increasingly specialized in terms of their upstream activities, but gradually increased Japan's dependency on

inputs provided by neighboring countries over the period of analysis. The Korean manufacturing sectors were shown to be quite unique in this respect as they increased their self-sufficiency, which was seen in their decreasing VS/EX ratio and increasing domestic procurement ratios.

Developing economies such as SE4 and China had weak local supplier bases, particularly in machinery sectors, so their participation within regional production networks initially increased their dependency on imported inputs. It should be noted, however, that developing countries in East Asia have started to increase their own exports of intermediate inputs and have thus become more specialized in their upstream manufacturing activities. Simultaneously, developed countries in the region such as Japan and Korea have been shown to be increasingly specialized in their upstream activities.

Regarding domestic procurement ratios, machinery sectors were shown to have different trends depending on the characteristics of industries and industrial policies adopted by respective countries. In particular, electrical machinery had relatively low domestic procurement ratios on a downward trend, while transport machinery exhibited the opposite trend.

Taken together, the findings of this study show that as a result of the continuous advancement of production networks, the development of local supplier bases does not necessarily lead to a deepening of domestic linkages, except in industries that have strong tendencies toward agglomeration; rather, intra-industry trade of materials and parts has increased in East Asia and external linkages are further strengthened at the expense of domestic linkages. In such industries, the benefits of advancement of production networks, including the benefits obtainable from relocating

labor-intensive manufacturing activities to less developed countries, exceed the benefits of agglomeration. The results of this study suggests that more policy efforts should be made to strengthen local supplier bases, so that they will lead to either the formation of domestic linkages within particular countries, or the formation of external linkages across borders. However, it is not policy makers but market mechanism that will determine which industries are likely to strengthen domestic linkages or external linkages.

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Appendix 1

Table 4 indicates the Grubel-Lloyd (GL) indices for intermediate inputs (i.e., materials, parts, and components) in East Asia. The Grubel-Lloyd index for sector i in country S is calculated as follows:

$$GL_i^S = 1 - \frac{\left| \Sigma_{R \neq S}^{G} \Sigma_{j=1}^{n} X_{ij}^{SR} - \Sigma_{R \neq S}^{G} \Sigma_{j=1}^{n} X_{ij}^{RS} \right|}{\Sigma_{R \neq S}^{G} \Sigma_{j=1}^{n} X_{ij}^{SR} + \Sigma_{R \neq S}^{G} \Sigma_{j=1}^{n} X_{ij}^{RS}}, \text{ where } 0 \leq GL_i^S \leq 1.$$

The analysis clearly shows that the Grubel-Lloyd indices increased for both materials and parts in all included countries, implying that intra-industry trade of materials and parts have increased in East Asia. In particular, the GL indices for machinery parts significantly increased: for instance, the GL index in the SE4 increased from 0.01 to 0.59 during the period 1975-2005, while that in Korea increased from 0.04 to 0.74.

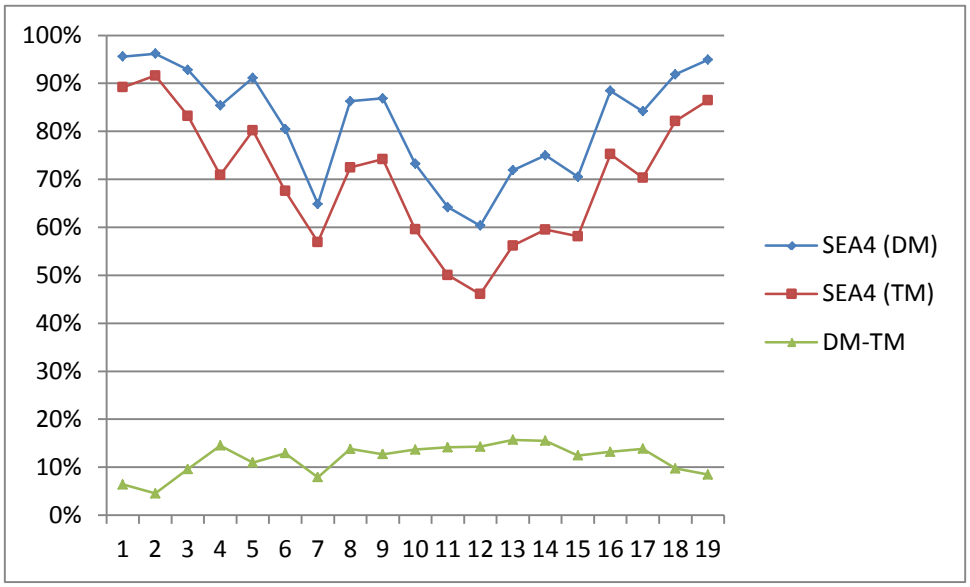
[Appendix: Table 4 around here]

Appendix 2

Figures 3-1 to 3-4 show the VS/EX and VS1/EX ratios for respective manufacturing sectors in 2005 (those for 1975 and 1990 are not reported here due to limitations of space). As expected from Figure 2, many sectors in the SE4, China, and Korea have higher VS/EX ratios than VS1/EX ratios, while those in Japan demonstrate an opposite trend. Also notable is that manufacturing sectors, such as metal products in the SE4, wooden furniture and other wooden products in Japan and Korea, exhibit very high VS/EX ratios, while pulp and paper in Japan demonstrates a relatively high VS1/EX ratio.

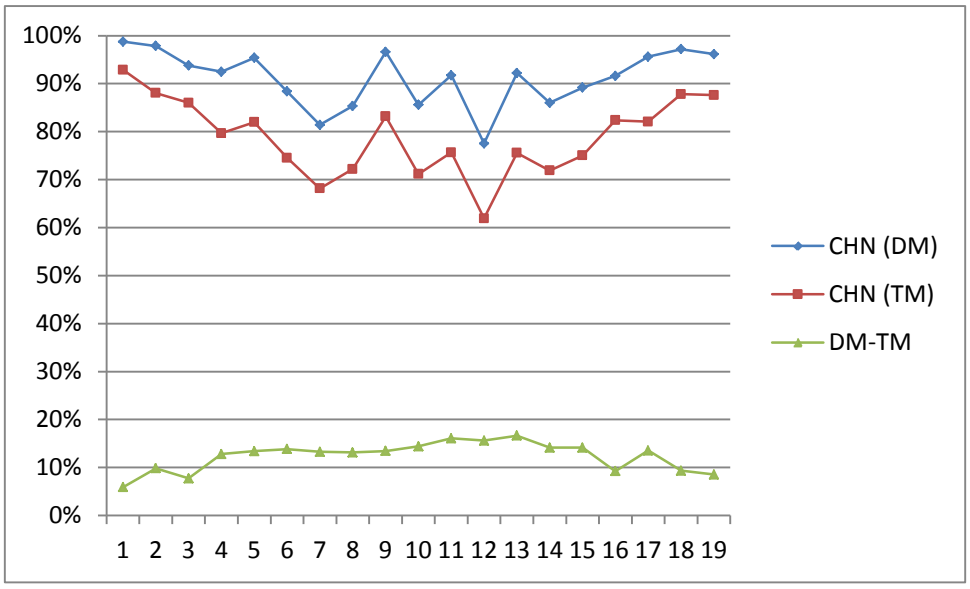
[Appendix: Figures 3-1 to 3-4]

Figure 1-1 Local content in direct and total measures, SE4, 2005



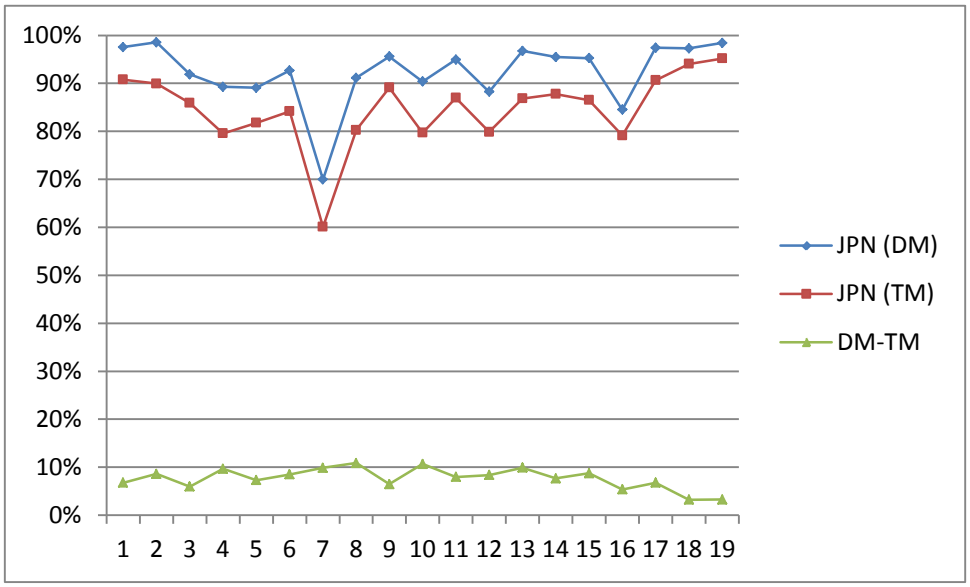
Data: Asian International Input-Output Table, 2005

Figure 1-2 Local content in direct and total measures, China, 2005



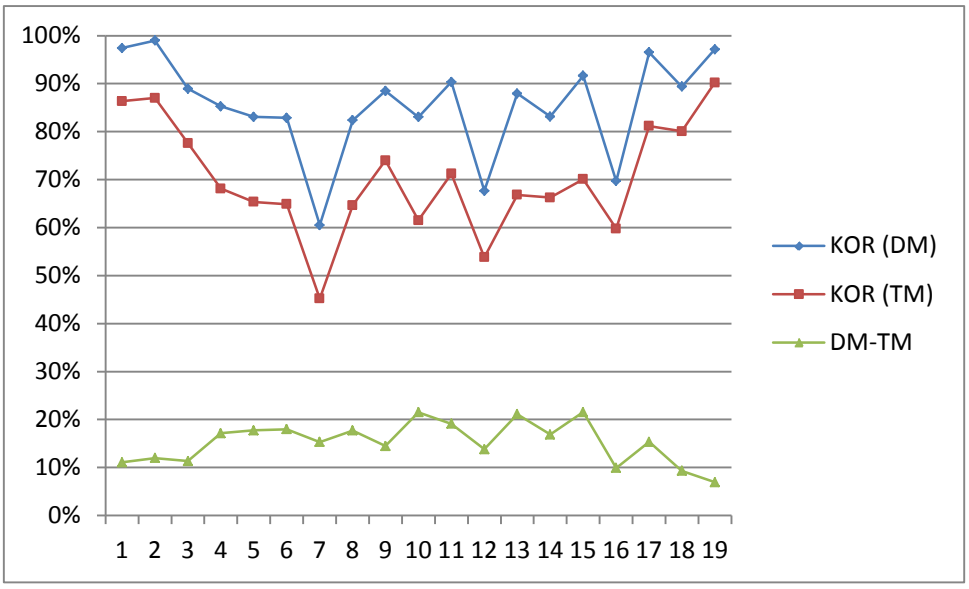
Data: Asian International Input-Output Table, 2005

Figure 1-3 Local content in direct and total measures, Japan, 2005



Data: Asian International Input-Output Table, 2005

Figure 1-4 Local content in direct and total measures, Korea, 2005



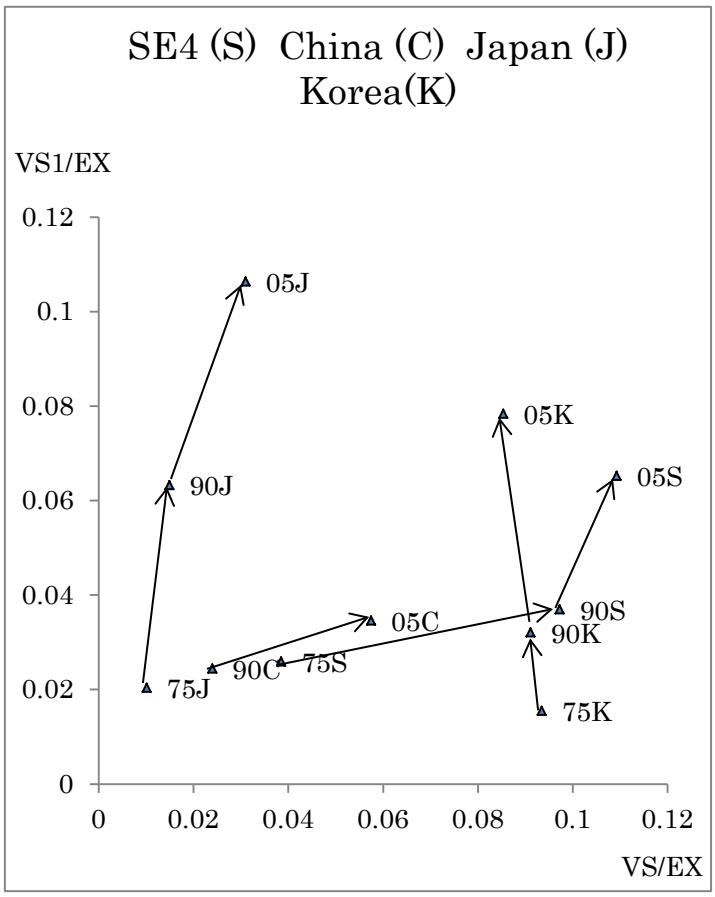
Data: Asian International Input-Output Table, 2005

1) Sector classification in Figures 1-1 to 1-4: 1 Agriculture, livestock, forestry, and fishery; 2 Mining and quarrying; 3 Food, beverage, and tobacco; 4 Textile, leather, and the products thereof; 5 Wooden furniture and other wooden products; 6 Pulp and paper; 7 Chemical products (including petroleum and petroleum products); 8 Rubber products; 9 Non-metallic mineral products; 10 Metal products; 11 General

machinery; 12 Electrical machinery; 13 Transport machinery; 14 Precision machinery; 15 Other manufacturing products; 16 Electricity, gas, and water supply; 17 Construction; 18 Trade and transport; 19 Services (including public administration).

2) DM: direct measure; TM: total measure.

Figure 2 VS/EX and VS1/EX ratios (SE4, China, Japan, Korea)



Data: Asian International Input-Output Table, 1975, 1990, 2005

Table 1 Domestic procurement ratios for machinery sectors

	SE4			China			Japan			Korea		
	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM
GM 75	46	36	10	NA	NA	NA	97	85	12	77	49	28
GM 90	45	32	13	93	82	11	97	88	9	80	59	21
GM 05	53	34	19	89	68	21	92	80	12	87	60	27
EM 75	63	50	13	NA	NA	NA	95	83	13	58	37	21
EM 90	39	30	8	80	68	12	94	86	8	66	47	19
EM 05	50	32	18	73	54	19	83	72	12	57	39	18
TrM 75	45	36	9	NA	NA	NA	98	86	13	65	42	23
TrM 90	46	34	13	83	72	11	98	89	9	85	62	22
TrM 05	61	39	22	90	69	21	96	83	13	85	58	27
PM 75	70	57	13	NA	NA	NA	96	85	11	48	32	15
PM 90	58	43	15	84	73	11	94	86	8	73	54	19
PM 05	64	41	22	81	61	19	92	80	13	76	53	24

Data: Asian International Input-Output Table, 1975, 1990, 2005

1) GM: General machinery; EM: Electrical machinery; TrM: Transport machinery; PM: Precision machinery;

2) DM: direct measure; TM: total measure

Table 2-1 Domestic procurement ratios for materials and parts (General machinery)

	SE4			China			Japan			Korea		
	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM
CP 75	53	29	24	NA	NA	NA	92	80	12	87	55	32
CP 90	64	33	31	97	78	18	96	79	16	91	49	41
CP 05	78	40	38	97	62	36	94	64	30	94	56	38
MP 75	49	26	22	NA	NA	NA	98	91	8	84	44	39
MP 90	45	21	24	93	81	13	99	88	11	90	60	31
MP 05	45	20	25	95	71	24	98	83	15	94	65	29
NP 75	72	41	31	NA	NA	NA	98	95	3	76	55	21
NP 90	67	48	19	99	97	2	97	92	5	93	78	14
NP 05	64	40	24	96	88	7	91	85	6	79	61	18
PA 75	24	12	11	NA	NA	NA	96	92	5	59	38	21
PA 90	26	12	15	90	77	13	95	92	3	66	51	14
PA 05	42	23	19	86	70	16	88	81	7	82	65	17

Data: Asian International Input-Output Table, 1975, 1990, 2005

Table 2-2 Domestic procurement ratios by materials and parts (Electrical machinery)

	SE4			China			Japan			Korea		
	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM
CP 75	49	30	19	NA	NA	NA	95	80	15	80	47	33
CP 90	39	21	18	95	75	20	95	78	17	73	40	32
CP 05	52	28	24	98	58	40	92	61	31	46	32	14
MP 75	63	38	26	NA	NA	NA	88	77	11	77	33	45
MP 90	23	10	14	96	81	15	88	74	13	78	43	35
MP 05	48	17	31	97	69	28	82	65	18	73	40	33
NP 75	77	58	19	NA	NA	NA	98	94	4	49	33	17
NP 90	57	39	18	80	82	−2	97	91	6	92	80	12
NP 05	82	43	39	97	83	14	92	84	8	86	66	20
PA 75	43	25	18	NA	NA	NA	96	92	4	40	25	15
PA 90	12	6	5	59	30	29	93	90	3	51	34	17
PA 05	37	18	20	47	20	27	73	60	13	43	24	19

Data: Asian International Input-Output Table, 1975, 1990, 2005

Table 2-3 Domestic procurement ratios by materials and parts (Transport machinery)

	SE4			China			Japan			Korea		
	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM
CP 75	66	28	38	NA	NA	NA	96	81	15	74	47	27
CP 90	56	27	29	93	74	19	94	80	15	87	48	38
CP 05	79	40	40	98	61	37	88	66	22	90	54	36
MP 75	43	17	25	NA	NA	NA	99	91	7	63	32	32
MP 90	39	17	23	85	70	15	97	84	13	84	56	28
MP 05	41	18	22	96	71	25	94	80	14	78	54	25
NP 75	82	41	41	NA	NA	NA	99	96	3	79	43	36
NP 90	72	49	23	99	95	4	95	91	4	89	75	14
NP 05	38	28	10	95	87	7	95	90	5	82	62	20
PA 75	25	17	9	NA	NA	NA	98	96	2	64	48	16
PA 90	28	21	8	74	53	21	98	96	2	90	82	7
PA 05	63	46	17	88	72	16	97	90	7	92	78	14

Data: Asian International Input-Output Table, 1975, 1990, 2005

Table 2-4 Domestic procurement ratios by materials and parts (Precision machinery)

	SE4			China			Japan			Korea		
	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM	DM	TM	DM−TM
CP 75	63	37	25	NA	NA	NA	85	78	7	82	51	31
CP 90	71	36	35	94	76	19	97	79	19	87	46	40
CP 05	69	34	34	99	61	38	96	65	30	90	54	36
MP 75	79	46	33	NA	NA	NA	97	90	7	85	37	48
MP 90	76	37	39	86	72	13	94	80	14	84	52	32
MP 05	47	18	29	100	74	26	94	76	18	96	60	36
NP 75	61	44	17	NA	NA	NA	97	94	3	57	42	14
NP 90	58	47	11	99	94	4	92	89	4	85	75	10
NP 05	57	40	17	34	50	−16	84	82	3	64	53	11
PA 75	71	66	4	NA	NA	NA	94	90	4	4	1	3
PA 90	38	25	13	39	20	19	90	85	5	31	18	13
PA 05	72	56	16	27	11	16	47	36	10	51	29	22

Data: Asian International Input-Output Table, 1975, 1990, 2005

1) CP: Chemical products; MP: Metal products; NP: Non-metallic mineral products; PA: Parts for own sector (e.g., general machinery parts used by the general machinery sector).
2) DM: direct measure, TM: total measure.

Table 3-1 Decomposition of VS by trade partner

	SE4	CHN	JPN	KOR	TWN	SGP	USA
SE4 75	0	NA	69	1	NA	5	24
SE4 90	0	5	46	6	9	8	26
SE4 05	0	20	35	10	8	9	18
CHN 75	NA	NA	NA	NA	NA	NA	NA
CHN 90	7	0	45	5	16	2	26
CHN 05	12	0	35	23	12	4	15
JPN 75	11	NA	0	7	NA	2	81
JPN 90	8	9	0	12	9	2	59
JPN 05	16	27	0	16	10	3	29
KOR 75	5	NA	61	0	NA	0	34
KOR 90	3	0	57	0	4	1	34
KOR 05	6	19	41	0	7	4	22

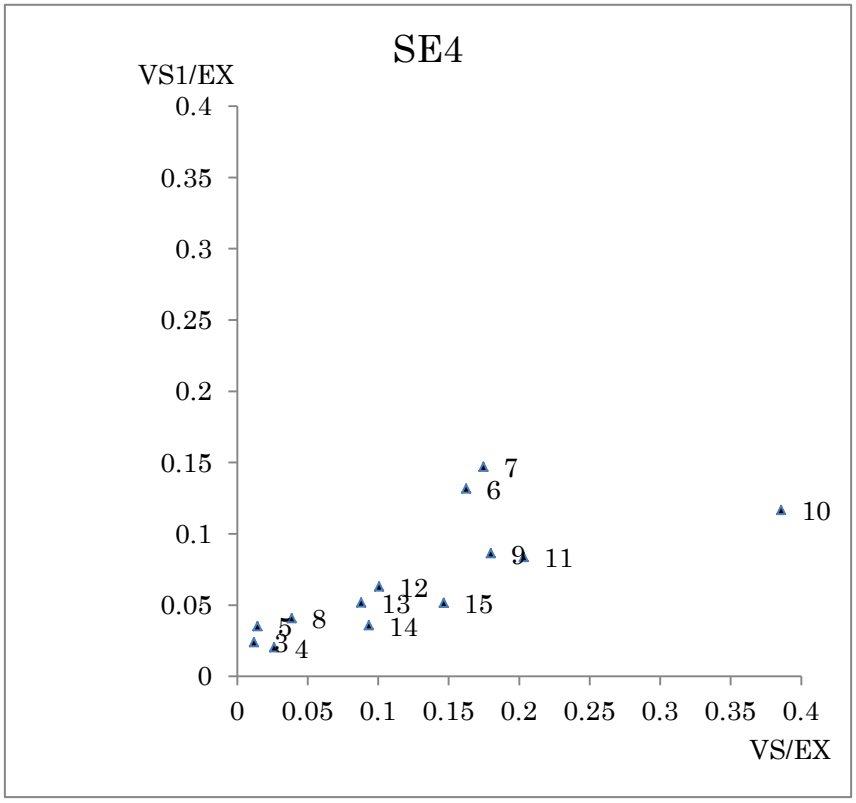
Data: Asian International Input-Output Table, 1975, 1990, 2005

Table 3-2 Decomposition of VS1 by trade partner

	SE4	CHN	JPN	KOR	TWN	SGP	USA
SE4 75	0	NA	34	12	NA	28	27
SE4 90	0	5	17	8	13	42	15
SE4 05	0	30	14	9	12	26	9
CHN 75	NA	NA	NA	NA	NA	NA	NA
CHN 90	18	0	26	1	2	36	17
CHN 05	23	0	17	17	16	11	17
JPN 75	16	NA	0	22	NA	9	52
JPN 90	14	4	0	18	23	21	20
JPN 05	19	28	0	18	19	6	10
KOR 75	5	NA	55	0	NA	4	37
KOR 90	16	4	25	0	15	16	24
KOR 05	13	46	12	0	16	5	8

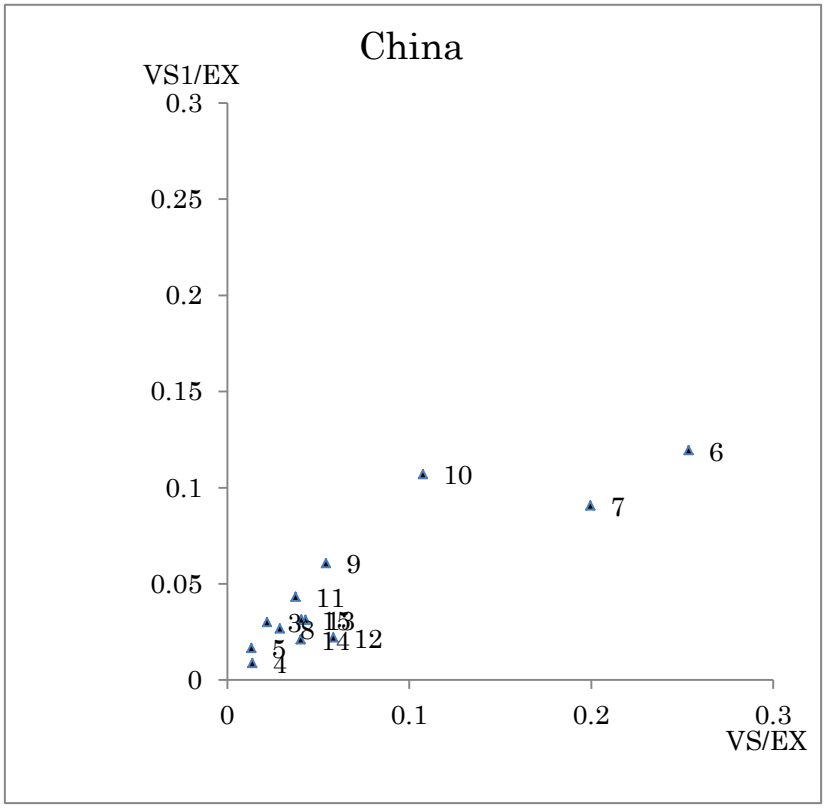
Data: Asian International Input-Output Table, 1975, 1990, 2005

Appendix: Figure 3-1 VS/EX and VS1/EX ratios, SE4, 2005



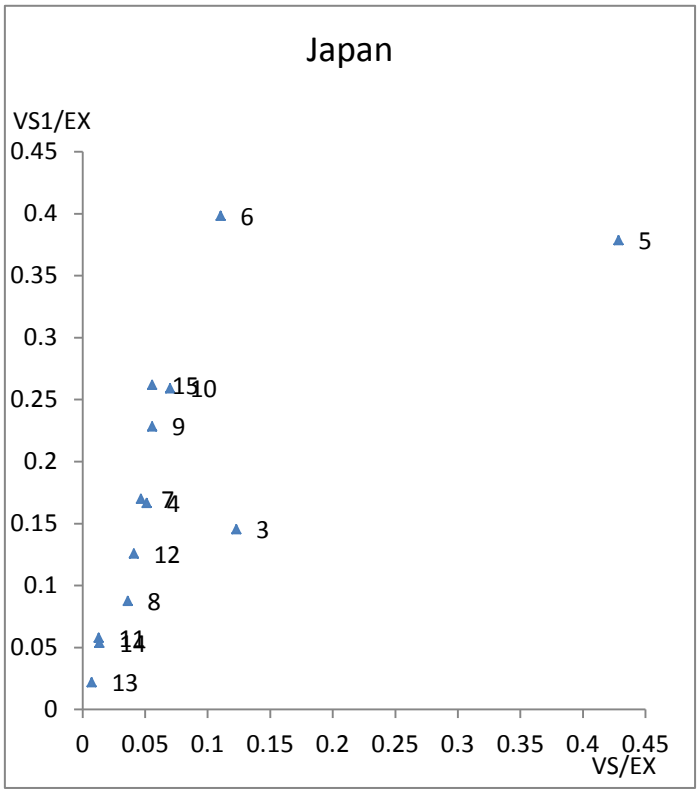
Data: Asian International Input-Output Table, 2005

Appendix: Figure 3-2 VS/EX, VS1/EX, China, 2005



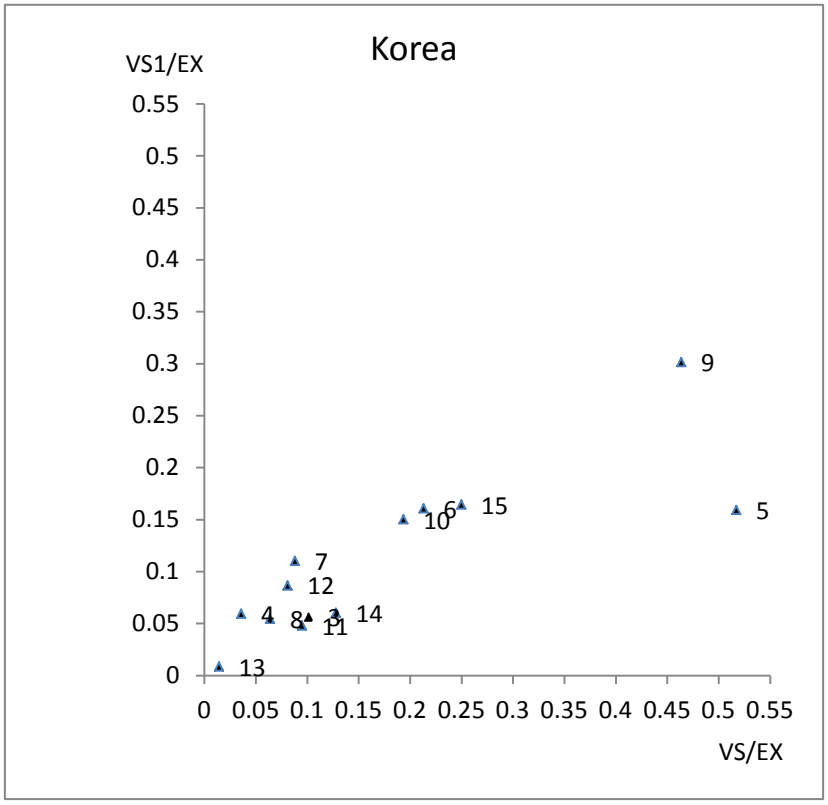
Data: Asian International Input-Output Table, 2005

Appendix: Figure 3-3 VS/EX, VS1/EX, Japan, 2005



Data: Asian International Input-Output Table, 2005

Appendix: Figure 3-4 VS/EX, VS1/EX, Korea, 2005



Data: Asian International Input-Output Table, 2005

1) For sector classification in Figures 3-1 to 3-4, see the footnote of Figures 1-1 to 1-4.

Appendix: Table 4 GL indices for materials and parts (intermediate transactions only)

	SE4			China			Japan			Korea		
	1975	1990	2005	1975	1990	2005	1975	1990	2005	1975	1990	2005
CP	0.40	0.47	0.76	NA	0.70	0.46	0.89	0.94	0.78	0.24	0.51	0.76
MP	0.70	0.52	0.59	NA	0.98	0.91	0.29	0.71	0.66	0.54	0.96	0.99
NP	0.39	0.65	0.91	NA	0.54	0.56	0.21	0.86	0.76	0.69	0.89	0.49
GM	0.12	0.50	0.76	NA	0.84	0.74	0.29	0.31	0.40	0.36	0.29	0.79
EM	0.69	0.96	0.94	NA	0.72	0.81	0.40	0.46	0.69	0.84	0.87	0.83
TrM	0.01	0.05	0.59	NA	0.17	0.69	0.52	0.34	0.50	0.04	0.47	0.74
PM	0.91	0.64	0.88	NA	0.69	0.76	0.38	0.43	0.74	0.51	0.35	0.94

Data: Asian International Input-Output Table, 1975, 1990, 2005

1) CP: Chemical products (materials); MP: Metal products (materials); NP: Non-metallic mineral products (materials); GM: General machinery (parts); EM: Electrical machinery (parts); TrM: Transport machinery (parts); PM: Precision machinery (parts).