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**Multi Country Vertical Specialization Dependence:
A New Approach to the Vertical Specialization Study**

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Abstract

This paper attempts to reveal the vertical specialization dependence relationship in East Asian countries using the multi country vertical specialization dependence modeling based on the Asian International Input-Output data. Use of multi country model allows us to study the country-wise vertical specialization association that is not possible with the single country model. More over, the multi country vertical specialization dependence modeling, a new approach to study the vertical specialization (imported intermediate goods to produce the export goods), enables us to explain the dependence on domestic intermediate goods and the dependence on other countries as well. The results show that the vertical specialization dependence on total import and group of USA, EU and ROW is high in general among the East Asian countries. However, it is also important to note that the vertical specialization dependence on 9 Asian countries and Hong Kong is relatively high as compared to non-regional countries. Such a situation of vertical specialization dependence in East Asia indicates the strong relationship (in terms of vertical specialization) among the Asian countries.

Keywords: International trade, Input-Output analysis, Vertical specialization, East Asia

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1. Introduction

High economic growth and strengthened regional cooperation in East Asia may be considered as an outcome of expansion in international trade (export and import). This paper attempts to reveal the vertical specialization dependence (i.e., relationship between the export and the intermediate goods necessary to produce the export goods) in East Asia using a new approach of multi country vertical specialization dependence modeling based on the Asian International Input-Output data.

The existing vertical specialization studies relate the export and the imported intermediate goods to produce the export goods. Hummels et al. (2001) calculates the vertical specialization share, defined as export-weighted average of imported input goods to produce the export goods, in single country modeling framework. The single country model is incapable to distinguish the vertical specialization share subject to import from two different countries. As an extension to the single country model, Fujita (2006) considers such a problem and uses the multi country model to calculate the inter-country vertical specialization share using the Asian International Input-Output (AIIO) tables.

Economic theory relates the export of a country directly to the economic growth. If export escalates the import of intermediate goods, then the net effect of the export on the economic growth will decrease. It, therefore, becomes important to use the domestic intermediate goods to produce export goods. And hence, it is worthy to study a relationship between the domestic inputs and the export also. So far, the existing papers take no notice of the domestic inputs associated with production of the export goods. Further, incorporating effect of the domestic intermediate goods also in the vertical specialization study will improve our understanding about the domestic and

international dependence to produce export goods. Therefore, the current research takes an opportunity to address the domestic inputs used to produce the export goods in vertical specialization studies. To distinguish two types of vertical specialization (based on imported and domestic inputs) import vertical specialization and domestic vertical specialization are defined and then estimated in the multi country framework.

AIIO Tables published by Institute of Developing Economies (IDE) are used as a source of data. Analysis based on the recently published AIIO table for the year 2000 and use of the AIIO table with maximum industry classification level are another contributions of this paper.

The results show that the vertical specialization dependence of East Asian countries on imported intermediate goods is relatively high and has increased significantly during 1990-1995-2000 in general. Further, the import vertical specialization dependence on 9 Asian countries and Hong Kong is relatively high and illustrates significant improvement that indicates a strong vertical specialization relationship and also growing regional integration in Asia from 1990-2000 in terms of import vertical specialization.

The remainder of this paper is organized as follows. Section 2 presents the analytical framework. Section 3 describes the data used in this study. Section 4 discusses the results of analysis. And finally, section 5 concludes the paper.

2. Analytical Framework

This section explains the concept of the vertical specialization used in the current paper and lists some differences compared to the definition in the existing studies. In a

single country model (Figure 1), let us assume that country 1 produces the total output of \mathbf{X}^1 using the domestic and imported intermediate goods¹ \mathbf{Z}^{11} and \mathbf{Z}^{31} respectively². Domestic production (\mathbf{F}^{11}) and the import (\mathbf{F}^{31}) fulfill the final demand in country 1. Finally, country 1 exports \mathbf{E}^1 to the ROW. Where (with respect to the n sector input-output table) \mathbf{X}^1 is the output vector of n dimension, \mathbf{Z}^{11} is the $n \times n$ matrix of domestic intermediate goods, \mathbf{Z}^{31} is the $n \times n$ matrix of imported intermediate goods, \mathbf{F}^{11} is the $n \times 1$ vector of final demand for domestic production, \mathbf{F}^{31} is the $n \times 1$ vector of final demand for imported goods, and \mathbf{E}^1 is the $n \times 1$ vector of exports.

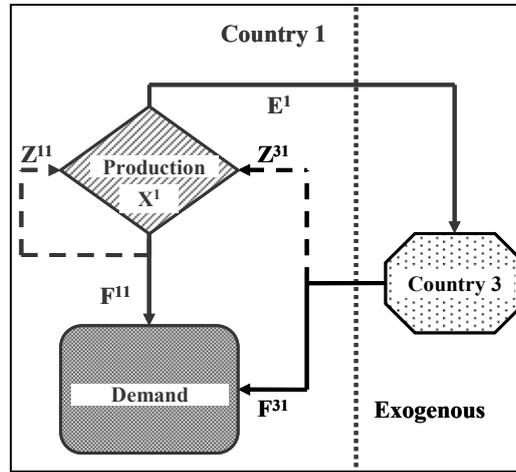


Figure 1: Flow of goods in single country model

The input-output method defines the domestic input coefficient matrix \mathbf{A}^{11} and imported input coefficient matrix \mathbf{A}^{31} as $\mathbf{Z}^{11} * (\hat{\mathbf{X}}^1)^{-1}$ and $\mathbf{Z}^{31} * (\hat{\mathbf{X}}^1)^{-1}$ respectively.. Any input coefficient a_{ij} of \mathbf{A}^{11} (or \mathbf{A}^{31}) denotes the domestic (or imported) inputs from sector i used to produce one unit of sector j 's output. In addition, the indirect production

¹ The production process requires the primary inputs (labor and capital) also. But, the current study ignores the effect of primary inputs as the paper deals with the requirement of the intermediate goods to produce the export goods.

² In single country model Rest of the World is denoted by Country 3, not Country 2, for the consistency with the two country model.

effects are accounted through the Leontief inverse³, i.e., $(\mathbf{I} - \mathbf{A}^{11})^{-1}$. Where $\hat{\mathbf{X}}^1$ is the diagonal matrix of vector \mathbf{X}^1 and \mathbf{I} is the identity matrix.

The previous studies (Hummels et al., 2001 and Fujita, 2006) define vertical specialization as the imported intermediate goods required to produce the export goods. And, they also defines vertical specialization share of a country as a ratio of vertical specialization to the total export. The vertical specialization (VS) and the vertical specialization share (VSS) for country 1 calculated from the input-output table with n industrial sectors are given as $VS = \mathbf{u}\mathbf{A}^{31}(\mathbf{I} - \mathbf{A}^{11})^{-1}\mathbf{E}^1$ and $VSS = \frac{\mathbf{u}\mathbf{A}^{31}(\mathbf{I} - \mathbf{A}^{11})^{-1}\mathbf{E}^1}{\mathbf{u}\mathbf{E}^1}$ respectively. Where \mathbf{u} is n dimension row vector of 1's, \mathbf{A}^{31} is the $n \times n$ imported input coefficient matrix, \mathbf{I} is the identity matrix of size n , \mathbf{A}^{11} is the $n \times n$ domestic input coefficient matrix, and \mathbf{E} is the n dimension column vector of total exports.

The definition of vertical specialization used in existing researches has significant importance in the international trade studies. On the other hand, incorporating effect of the domestic intermediate goods, which were excluded in the previous studies, also in the vertical specialization study will improve our understanding about the domestic and international dependence to produce export goods. Therefore, the present paper defines two types of vertical specialization as (1) import vertical specialization (VS_{imp}), and (2) domestic vertical specialization (VS_{dom}). The former uses the existing definition of vertical specialization i.e., imported inputs required to produce the export goods ($VS_{imp} = \mathbf{u}\mathbf{A}^{31}(\mathbf{I} - \mathbf{A}^{11})^{-1}\mathbf{E}^1$) and the latter is interpreted as the domestic input requirements to produce export goods ($VS_{dom} = \mathbf{u}\mathbf{A}^{11}(\mathbf{I} - \mathbf{A}^{11})^{-1}\mathbf{E}^1$). Then, the imported

³ See any of the Input-Output Analysis texts (for example, UN, 1999) for the details and derivations, which are out of the scope of this paper, of the Leontief inverse.

vertical specialization dependence (VSD_{imp}) for export is defined as the ratio of the imported input requirement to the total input requirement ($VSD_{imp} = \frac{VS_{imp}}{VS_{imp} + VS_{dom}}$).

Further, domestic vertical specialization dependence for export (VSS_{dom}) is given as $VSD_{dom} = \frac{VS_{dom}}{VS_{imp} + VS_{dom}} = 1 - VSS_{imp}$.

The single country model that measures the degree of globalization (and hence the degree of nationalization) in intermediate input markets is not capable of catching the vertical specialization relationship with any particular foreign country or group of countries. Country specific vertical specialization relationship study allows us to measure the degree of economic or regional integration between two countries or group of countries. For this reason, a multi country model is necessary to study the country-wise vertical specialization association. Figure 2 represents flow of the goods in the two country framework, which is an extension to the single country model. In figure 2, \mathbf{Z}^{kl} ($k = 1, 2, 3$ and $l = 1, 2$) is $n \times n$ transaction matrix of intermediate goods supplied from country k to country l ; \mathbf{F}^{kl} is $n \times 1$ vector of final goods produced in country k that are consumed in country l ; \mathbf{X}^l is the total production of endogenous country l ; and \mathbf{E}^l is the export of the country l to the exogenous country i.e., country 3. The total export of endogenous countries \mathbf{Et}^l is the sum of exports (intermediate and final goods) to the other endogenous country and exogenous country.

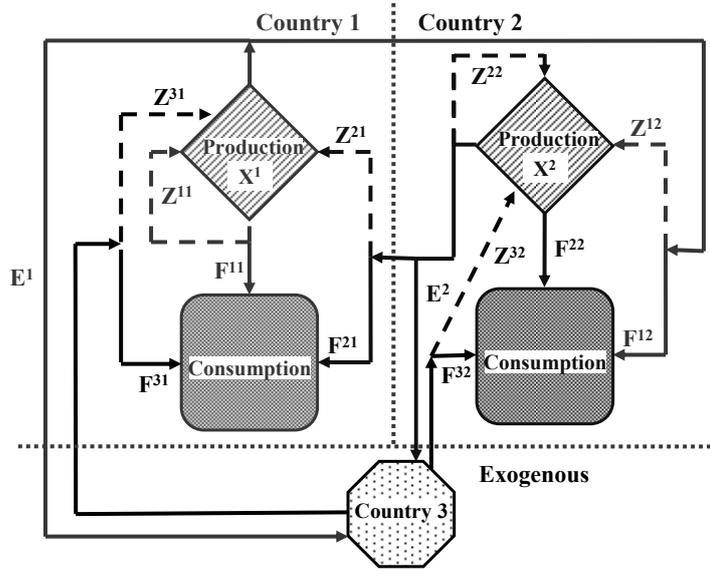


Figure 2: Flow of goods in two country model

For country 1, the domestic and the imported vertical specialization are given as $VS_{dom}^1 = \mathbf{uA}^{11}(\mathbf{I} - \mathbf{A}^{11})^{-1} \mathbf{E}t^1$ and $VS_{imp}^1 = \mathbf{u}(\mathbf{A}^{21} + \mathbf{A}^{31})(\mathbf{I} - \mathbf{A}^{11})^{-1} \mathbf{E}t^1$ respectively if the single country model concept is followed. Such an extension from single country model to the multi-country model enables us to measure the country-wise vertical specialization effect (the imported vertical specialization can be separated into two parts as the effect of country 2 (i.e., $\mathbf{uA}^{21}(\mathbf{I} - \mathbf{A}^{11})^{-1} \mathbf{E}t^1$) and the effect of exogenous country 3 (i.e., $\mathbf{uA}^{31}(\mathbf{I} - \mathbf{A}^{11})^{-1} \mathbf{E}t^1$). However, this calculation ignores the effect of the production of intermediate goods in foreign country that uses the intermediate goods supplied from country 1.

Fujita (2006, Page 459-462) excellently attempted to address the production technology associated foreign country in the vertical specialization calculations. However, his work does not fully consider such technology. The effect due to the production in USA, an endogenous country, has been excluded because the study focuses on the group of 9 Asian countries.

To explain vertical specialization in the two country model let us assume two endogenous countries (Country 1 and Country 2), an exogenous country (Country 3) and figure 2 specify the flow of goods (intermediate goods, final demand goods and export to exogenous country are respectively denoted by \mathbf{Z} 's, \mathbf{F} 's and \mathbf{E} 's) among these countries. Further, country 1 produces \mathbf{X}^1 and \mathbf{X}^2 is country 2's production. For the economies with n production sectors \mathbf{Z} 's are the $n \times n$ matrices, \mathbf{X} 's are column vector on n dimension and \mathbf{E} 's are n dimension column vector. In international input-output framework the international input coefficient matrix is defined as

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}^{11} & \mathbf{A}^{12} \\ \mathbf{A}^{21} & \mathbf{A}^{22} \\ \mathbf{A}^{31} & \mathbf{A}^{32} \end{bmatrix} = \begin{bmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{12} \\ \mathbf{Z}^{21} & \mathbf{Z}^{22} \\ \mathbf{Z}^{31} & \mathbf{Z}^{32} \end{bmatrix} \begin{bmatrix} \hat{\mathbf{X}}^1 & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{X}}^2 \end{bmatrix}^{-1}$$

Here, $\hat{\mathbf{X}}^j$ is the diagonal matrix of the vector \mathbf{X}^j , first superscript denotes the country of origin and second is the destination country. For example, \mathbf{Z}^{32} is the flow of intermediate goods from country 3 to country 2.

Further, the international Leontief inverse matrix, say \mathbf{B} , is the total production of goods in all the sectors and countries with direct and indirect effects to fulfill an unit final demand in each sector and country. Mathematically, \mathbf{B} is defined as

$$\mathbf{B} = \left[\begin{pmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{pmatrix} - \begin{pmatrix} \mathbf{A}^{11} & \mathbf{A}^{12} \\ \mathbf{A}^{21} & \mathbf{A}^{22} \end{pmatrix} \right]^{-1} = \begin{bmatrix} \mathbf{B}^{11} & \mathbf{B}^{12} \\ \mathbf{B}^{21} & \mathbf{B}^{22} \end{bmatrix}$$

Using the total intermediate input requirement matrix concept⁴ (Hasebe and Shrestha, 2006), the vertical specialization matrix, say \mathbf{VS} , can be defined as

⁴ Total intermediate input requirement matrix reveals the intermediate goods necessary to produce unit output with direct, indirect and exogenous country effect.

$$\mathbf{VS} = \begin{bmatrix} \mathbf{A}^{11} & \mathbf{A}^{12} \\ \mathbf{A}^{21} & \mathbf{A}^{22} \\ \mathbf{A}^{31} & \mathbf{A}^{32} \end{bmatrix} \begin{bmatrix} \mathbf{B}^{11} & \mathbf{B}^{12} \\ \mathbf{B}^{21} & \mathbf{B}^{22} \end{bmatrix} \begin{bmatrix} \mathbf{Et}^1 & \mathbf{0} \\ \mathbf{0} & \mathbf{Et}^2 \end{bmatrix}$$

$$= \begin{bmatrix} \mathbf{A}^{11}\mathbf{B}^{11}\mathbf{Et}^1 + \mathbf{A}^{12}\mathbf{B}^{21}\mathbf{Et}^1 & \mathbf{A}^{11}\mathbf{B}^{12}\mathbf{Et}^2 + \mathbf{A}^{12}\mathbf{B}^{22}\mathbf{Et}^2 \\ \mathbf{A}^{21}\mathbf{B}^{11}\mathbf{Et}^1 + \mathbf{A}^{22}\mathbf{B}^{21}\mathbf{Et}^1 & \mathbf{A}^{21}\mathbf{B}^{12}\mathbf{Et}^2 + \mathbf{A}^{22}\mathbf{B}^{22}\mathbf{Et}^2 \\ \mathbf{A}^{31}\mathbf{B}^{11}\mathbf{Et}^1 + \mathbf{A}^{32}\mathbf{B}^{21}\mathbf{Et}^1 & \mathbf{A}^{31}\mathbf{B}^{12}\mathbf{Et}^2 + \mathbf{A}^{32}\mathbf{B}^{22}\mathbf{Et}^2 \end{bmatrix} = \begin{bmatrix} \mathbf{VS}^{11} & \mathbf{VS}^{12} \\ \mathbf{VS}^{21} & \mathbf{VS}^{22} \\ \mathbf{VS}^{31} & \mathbf{VS}^{32} \end{bmatrix}$$

Note that the vertical specialization matrix \mathbf{VS} includes the production technology effect of foreign country (\mathbf{B}^{21} in first column for country 1 and \mathbf{B}^{12} in second column for country 2) in the analysis, which was either disregarded or considered partially, in the existing studies.

Finally, Table 1 summarizes the mathematical definitions of vertical specialization, vertical specialization share (as defined in existing literatures) and the vertical specialization dependence (defined in the present paper).

	Vertical Specialization	Vertical Specialization Share	Vertical Specialization dependence
<i>Domestic</i>	\mathbf{uVS}^{11}	-	$\mathbf{uVS}^{11}/\mathbf{uVSt}^1$
<i>Import</i>	$\mathbf{u}(\mathbf{VS}^{21} + \mathbf{VS}^{31})$	$\mathbf{u}(\mathbf{VS}^{21} + \mathbf{VS}^{31})/\mathbf{uEt}^1$	$\mathbf{u}(\mathbf{VS}^{21} + \mathbf{VS}^{31})/\mathbf{uVSt}^1$
<i>Import (Country 2)</i>	\mathbf{uVS}^{21}	$\mathbf{uVS}^{21}/\mathbf{uEt}^1$	$\mathbf{uVS}^{21}/\mathbf{uVSt}^1$
<i>Import (Country 3)</i>	\mathbf{uVS}^{31}	$\mathbf{uVS}^{31}/\mathbf{uEt}^1$	$\mathbf{uVS}^{31}/\mathbf{uVSt}^1$

Note: $\mathbf{VSt}^1 = \mathbf{VS}^{11} + \mathbf{VS}^{21} + \mathbf{VS}^{31}$ and \mathbf{u} is a row vector of 1s.

Table 1: Summary of vertical specialization measures

3. Data

The current paper uses the Asian Input-Output tables for years 1990, 1995 and 2000 that provides detailed information on intermediate goods, final goods and the export for

each of the endogenous countries. IDE publishes such tables periodically that consists 10 endogenous countries (Indonesia, In; Malaysia, Ma; the Philippines, Ph; Singapore, Si; Thailand, Th; China, Ch; Taiwan, Tw; Korea, Kr; Japan, Jp and the United States, Us), 2 exogenous countries (Hong Kong, HK and Rest of the world, ROW) and has maximum 78 production sectors⁵.

This research aims to light on the country level vertical specialization dependence in East Asia. Therefore, sector aggregation of the tables to the same number is not necessary. On the other hand, sector level analysis requires a correspondence on production sectors and the numbers in the tables for different years. However, the year 2000 table is aggregated to the 75 sector table so that the Leontief inverse matrix (**B**) could be calculated. It is, simply because a diagonal element for unclassified sector (Malaysia) in international input coefficient matrix (**A**) is one, or equivalently, zero in (**I – A**) which is a singular matrix.

4. Results

This section presents the vertical specialization results calculated from the maximum sector disaggregated Asian International Input-Output tables for years 1990, 1995 and 2000. Table 2 shows the comparison of growth rate (per 5 year) in vertical specialization share and vertical specialization dependences for 10 endogenous countries, including the non-Asian country USA, during the period 1990-1995 and 1995-2000. Growth per 5 year in the vertical specialization shares (calculation based on existing literatures) illustrate the significant increase in Asian countries during 1995-2000 period, except for the Singapore (-5.2%). The VSS growth in Singapore, Korea and Japan experienced

⁵ Year 1990 and 1995 tables are classified into 78 production sectors, whereas the number of sectors in the 2000 table is 76.

negative increment during the period 1990-1995. On the other hand, growth in the import vertical specialization dependence has same sign as that for the vertical specialization share except for Indonesia and Korea during 1990-1995 periods. Some of the sign differences in the vertical specialization share and the import vertical specialization dependence may arise as the later reflects the change in the intermediate goods due to change in the export. In contrast, the prior include the effects of change in the export and the change in the intermediate good.

Country	Period	VSS	VSD _{imp}	VSD _{dom}
Indonesia	1990-1995	4.8	-4.0	1.5
	1995-2000	11.3	7.3	-2.6
Malaysia	1990-1995	48.4	38.6	-23.7
	1995-2000	36.4	19.1	-21.3
Philippines	1990-1995	13.1	18.9	-12.9
	1995-2000	37.4	17.5	-16.3
Singapore	1990-1995	-5.6	-15.8	35.7
	1995-2000	-5.2	-2.4	3.4
Thailand	1990-1995	5.1	4.4	-2.9
	1995-2000	20.8	11.0	-7.7
China	1990-1995	48.0	41.1	-4.5
	1995-2000	16.1	10.0	-1.6
Taiwan	1990-1995	10.8	19.5	-10.6
	1995-2000	5.2	9.5	-7.0
Korea	1990-1995	-4.3	3.4	-1.6
	1995-2000	9.4	3.1	-1.5
Japan	1990-1995	-22.8	-15.9	2.2
	1995-2000	17.5	15.4	-1.8
USA	1990-1995	23.5	21.2	-2.0
	1995-2000	8.0	19.3	-2.2

Unit: percent per five year.

Table 2: Comparison of growth rate (per 5 year) in vertical specialization share (VSS) and vertical specialization dependences (VSD)

As it is mentioned in earlier sections that the existing studies deal only with the imported intermediate goods to produce the export goods, the current approach is capable of grasping the relationship with both imported and domestic intermediate goods necessary to produce the export goods. It is obvious that the sign for the import and the domestic dependence is opposite, the new methodology provides the magnitude of the both type of dependences. For example, in Singapore the dependence on imported intermediate goods has decreased by 15.8% from 1990 to 1995, whereas, during the same period the dependence on domestic intermediate goods has increased by 35.7%.

Figure 3 is the transition of import vertical specialization dependence on (a) total import, (b) import from USA, EU and ROW, (c) China, and (d) Japan respectively. Figure 3 (a) illustrates the increasing trend, in general, on the imported intermediate goods in 8 Asian countries. It indicates the globalization of the economy in terms of producing the export goods. If the regional vertical specialization relationship in Asia (excluding Japan) is considered, the regional dependence does not seem promising. The reasons are (1) the dependence on Japan and USA, EU and ROW are relatively high and (2) dependence on USA, EU and ROW has increased from 1995 to 2000. The low level of dependence on China is an illustration of dependence situation on other Asian endogenous countries (except Japan).

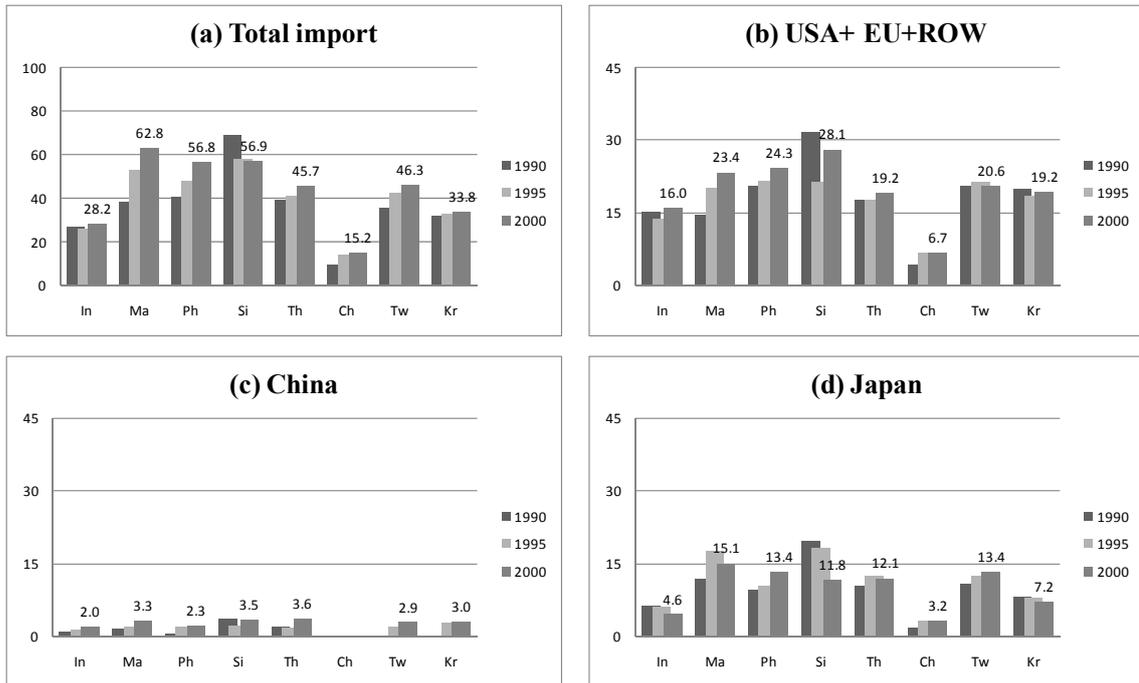


Figure 3: Transition of import vertical specialization dependence (percent) on total import, non-regional countries, China and Japan

Now to continue the analysis at the regional level, Figure 4 presents the import vertical specialization dependence on different Asian blocks. 8 endogenous East Asian countries, in general, shows relatively higher level of dependence on 9 Asian endogenous countries and Hong Kong as compared to ASEAN4, NIEs3+HK and EA8 +HK. Moreover, the dependence on A9+HK has increased significantly since 1990 to 2000. Singapore may be considered as an exception, because the import of Singapore is very high and the dependence on USA, EU and ROW has grown significantly from 1995 to 2000 (figure 3, b).

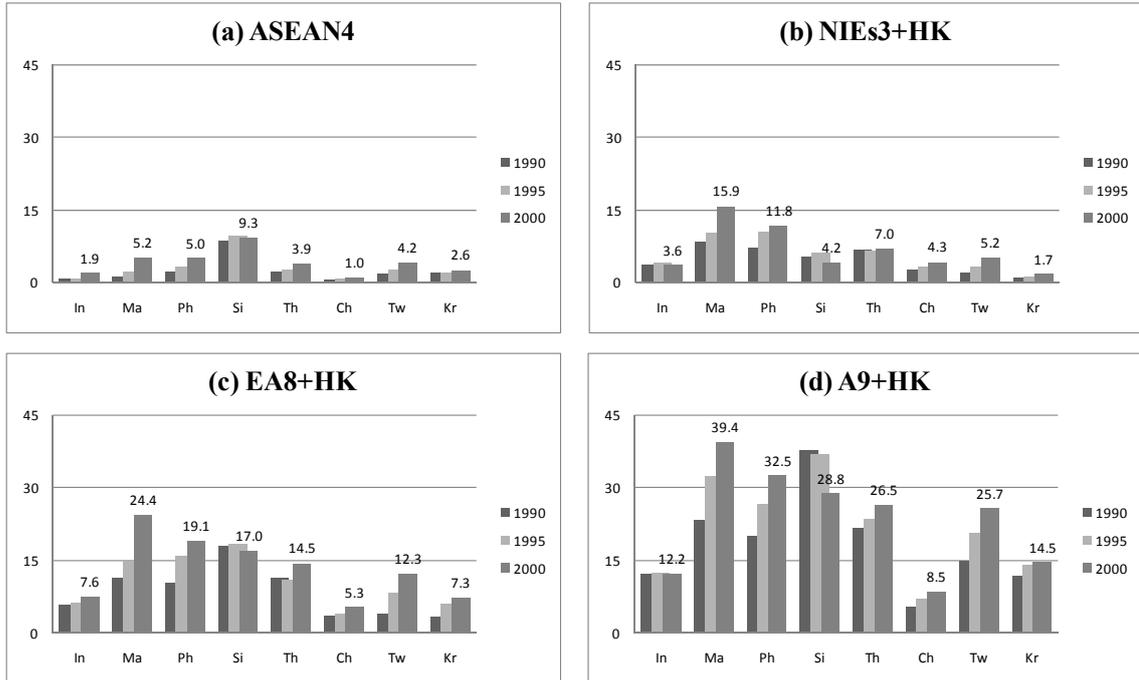


Figure 4: Transition of import vertical specialization dependence (percent) on different Asian blocks

The results described so far suggest that 8 East Asian countries depends more on imported intermediate goods rather than the domestic intermediate goods to produce the export goods and the non-regional partners (i.e., USA+EU+ROW and Japan) are main source of intermediate goods. In contrast, EA8 shows strong and increased dependence (1990-2000, except for Singapore) on A9+HK and gives a picture of growing regional integration in terms of vertical specialization.

5. Concluding Remarks

The present paper introduces a new methodology to reveal the vertical specialization relationship in East Asia using the multi country vertical specialization dependence modeling. The important advantages of the new approach are (1) possibility to study country-wise vertical specialization association, and (2) possibility to estimate the vertical specialization relationship with respect to imported and domestic intermediate

goods quantitatively. Moreover, use of highly disaggregated Asian International Input-Output tables allows us to include the precise sector level effect in the analysis.

The results show that the vertical specialization dependence of East Asia (i.e., EA8) on imported intermediate goods is relatively high and has increased significantly during 1990-1995-2000 in general. In the mean time, the high degree and increased dependence on USA+EU+ROW, as compared to Japan, shows East Asian countries preference on other countries over Japan. However, it is also important to notice that the import vertical specialization dependence on 9 Asian countries and Hong Kong is relatively high and illustrates significant improvement as compared to USA+EU+ROW. Such a situation is a clear picture of strong vertical specialization relationship and also an indication of growing regional integration in Asia from 1990-2000 in terms of import vertical specialization. Therefore, the economic integration in East Asia, that also includes Japan as an integrating partner, is more likely to create economically strong region in the world.

The current research focuses on the country level vertical specialization relationship in East Asia. However, the author understands the limit of a country level analysis in the vertical specialization studies. Detailed sector level analysis may fulfill such requirements to some extent, and hence, it is left for the future study.

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